Harlequin Duck (*Histrionicus histrionicus*): A Technical Conservation Assessment

Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project

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AUTHOR'S BIOGRAPHY

David Wiggins developed an early interest in Ornithology. During his high school years, he worked as a museum assistant under George Sutton and Gary Schnell at the University of Oklahoma. He later earned degrees from the University of Oklahoma (B.Sc. in Zoology), Brock University (M.Sc.- Parental care in Common Terns, under the supervision of Ralph Morris), and Simon Fraser University (Ph.D. – Selection on life history traits in Tree Swallows, under the supervision of Nico Verbeek). This was followed by a U. S. National Science Foundation Post-doctoral fellowship at Uppsala University in Sweden, where he studied life history evolution in Collared Flycatchers, and later a Fulbright Fellowship working on the reproductive ecology of tits (Paridae) in Namibia and Zimbabwe. He currently splits time between ecological research programs in Sweden and North America.

COVER PHOTO CREDIT

A pair of harlequin ducks on a breeding stream. © Daniel Bergmann (used with permission).

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF THE HARLEQUIN DUCK

Status

Harlequin ducks (*Histrionicus histrionicus)* have been the focus of management actions in eastern North America, the Pacific Northwest, and in the Rocky Mountain states due to concern over declining populations. Relative to other species of ducks, harlequin ducks occur at low population densities and exhibit high breeding site fidelity, low reproductive rates, and delayed reproduction. All of these traits contribute to making harlequin duck populations particularly slow to recover from habitat degradation or loss, or other factors that may lower duck survival (e.g. marine pollution). The species apparently bred in small numbers in Colorado in the late 1800s but subsequently became extirpated there, likely as a result of habitat degradation related to mining activities (e.g., timber harvesting, contamination of water supplies). More recently, harlequin ducks have disappeared from former breeding sites in Idaho and Montana.

Within USDA Forest Service Region 2, harlequin ducks breed along relatively large, fast-moving, mountain streams with gradients of 1 to 7 percent. Breeding streams are characterized by rocky substrates that support the benthic macro-invertebrates upon which the ducks feed, as well as large numbers of rapids/riffle areas interspersed with eddies. Water quality appears to be very important for successful foraging, with clear, low-acid water being optimal.

The primary factors thought to be responsible for local declines in the number of harlequin ducks are the degradation of breeding streams, human disturbance during the breeding season, and, in some areas, mortality due to hunting during the winter season. Harlequin duck breeding success is known to decrease during years of high and early spring runoff. In addition, activities such as logging, road-building, and mining may act to increase sedimentation along breeding streams, increase disturbance to nesting birds, and facilitate easier access to remote breeding sites. Mining may also lead to stream acidification and heavy metals pollution. As the vast majority of Region 2 harlequin ducks breed on National Forest System lands, human recreation use of breeding streams during the summer months has the potential to cause stream abandonment or to decrease reproductive success. Hunting of harlequin ducks along the West Coast wintering grounds may reduce local populations.

As harlequin ducks are relatively rare, there have been no studies in Region 2 that have identified which, if any, of the above threats are currently affecting population growth in the region. Information on these potential threats, as well as a complete picture of the distribution of breeding birds in Wyoming, are two pieces of information needed for successful conservation of the species. Other critical information needs include a better understanding of the factors affecting stream use by harlequin ducks and more standardized population monitoring.

Harlequin ducks breed in habitats that are particularly susceptible to forest management activities, water development projects, and human recreational use. Although the number of pairs breeding in Region 2 appears stable, the small size of this population (currently estimated at 15 to 20 pairs) warrants careful attention from land managers.

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INTRODUCTION

This conservation assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), USDA Forest Service (USFS). The harlequin duck is the focus of an assessment because it is listed as a sensitive species by Region 2 (**Figure 1**). Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance and/or in habitat capability that would reduce its distribution [FSM 2670.5 (19)]. A sensitive species may require special management, so knowledge of its biology and ecology is crucial. This assessment addresses the biology, ecology, and conservation status of the harlequin duck throughout its range, but with an emphasis on Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide land managers, biologists, and the public a thorough discussion of the biology, ecology, and conservation of certain species based on current scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop prescriptive management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, this assessment cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

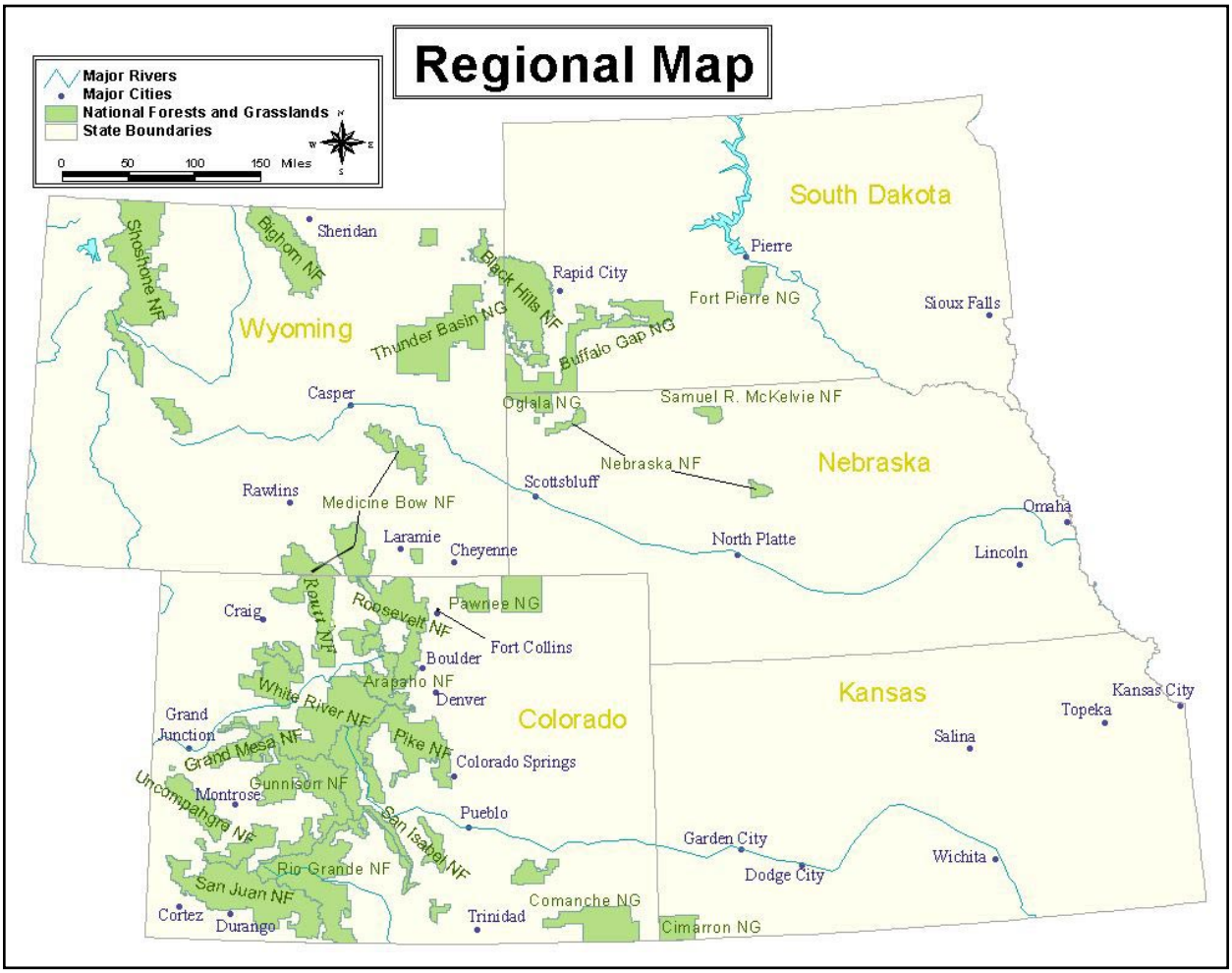


Figure 1. Map of national forests and grasslands within USDA Forest Service Region 2.

Scope and Limitations of Assessment

The harlequin duck conservation assessment examines the biology, ecology, conservation, and management of this species with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although a majority of the literature on the species originates from field investigations outside the region, to the extent possible, this document attempts to place that literature in the ecological and social context of the central and southern Rocky Mountains. Similarly, this assessment is concerned with the reproductive behavior, population dynamics, and other characteristics of harlequin ducks in the context of the current environment. The evolutionary environment of the species is considered in conducting the synthesis, but it is placed in current context.

In producing the assessment, I reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on harlequin ducks are referenced in the assessment, nor were all published materials considered equally reliable. The assessment emphasizes refereed literature because this is the accepted standard in science. I did choose to use some non-refereed literature in the assessment, when refereed publications were not unavailable, but these were regarded with greater skepticism.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, strong inference, as described by Platt, suggests that experiments will produce clean results (Hillborn and Mangel 1997), as may be observed in certain physical sciences. The geologist, T. C. Chamberlain (1897), suggested an alternative approach to science where multiple competing hypotheses are confronted with observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools (e.g., experiments, modeling, logical inference). In some ways, ecological science is similar to geology because of the difficulty in conducting critical experiments and the reliance on observation, inference, and models to guide understanding of the world (Hillborn and Mangel 1997).

Confronting uncertainty, then, is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and when appropriate, alternative explanations are described. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted as sound approaches to understanding.

Publication of Assessment on the World Wide Web

To facilitate the use of these species conservation assessments, they are being published on the Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, Web publication facilitates revision of the assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the Web. This report was reviewed through a process administered by the Society for Conservation Biology, employing two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

In eastern Canada, the harlequin duck is currently listed as a species of special concern in (COSEWIC 2003) while populations in western Canada are not considered threatened. In the United States, harlequin ducks are not listed as federally threatened or endangered under the Endangered Species Act (U.S. Fish and Wildlife Service 1998). Harlequin ducks are listed as a sensitive species within USFS Regions 2 and 4. The Bureau of Land Management (BLM) State Director's Sensitive Species lists for Colorado (Bureau of Land Management 2000) and Wyoming (Bureau of Land Management 2001) do not include the harlequin duck. A summary of the management status of harlequin ducks within state and Partners

in Flight (PIF) Bird Conservation Plans is presented in **Table 1**. The harlequin duck is listed as a Level II Priority Species in the Wyoming plan (monitoring of population size is suggested; Cerovski et al. 2001), but it is not considered a Priority Species in the Colorado plan. PIF plans for other states within Region 2 have not been published, but harlequin ducks have never been recorded as breeding in South Dakota, Nebraska, or Kansas. Just outside Region 2, the harlequin duck is listed as a Priority Species in the Montana and Idaho state PIF plans (**Table 1**). The Natural Heritage Program has ranked harlequin ducks as G4, or apparently secure, although the population in eastern North America continues to be considered at risk. State and provincial Natural Heritage Program designations for the harlequin duck are shown in **Figure 2**.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

In Canada, the eastern population of harlequin ducks is currently considered Special Concern. It was downlisted in May 2001 following the establishment of a recovery program (see details in Montevecchi et al. 1995) in the 1990s when it was considered Endangered (Goudie 1990, COSEWIC 2003). In the United States, the Migratory Bird Treaty Act of 1918 (MBTA) establishes a federal prohibition, unless otherwise permitted by regulations, to "pursue, hunt, take, capture, kill, attempt to take, possess, offer for sale, sell, offer to purchase, purchase, export, at any time, or in any manner, any migratory bird, including any part, nest, or egg of any such bird" (16 U.S.C. 703). As with other waterfowl, the harlequin duck is protected by the provisions of the MBTA. Pursuant to the MBTA, the U.S. Fish and Wildlife Service establishes annual regulations governing the "take" of waterfowl species, within which the states set hunting seasons and bag limits. The USFS and the BLM published a Rocky Mountain harlequin duck conservation assessment in 1996 (Cassirer et al. 1996). A U.S. Rocky Mountain Recovery Team was formulated, but it is no longer active (F. Cassirer, personal communication 2004). Harlequin ducks have been designated as a sensitive species within USFS Regions 2 and 4; this designation has the effect of focusing attention on the species whenever forest plans are revised, or whenever local habitat management activities are planned.

Biology and Ecology

Systematics

Although two subspecies (eastern [*Histrionicus histrionicus histrionicus*] and western [*H. h. pacificus*]) were proposed by Brooks (1915), later summaries (e.g., American Ornithologists' Union 1957, Palmer 1976) did not recognize subspecies. Recent unpublished work has suggested that there are clear genetic differences between Pacific (including Rocky Mountain) and eastern populations of harlequin ducks (Scribner et al. 2000). However, differentiation within sub-populations is much stronger within the eastern range than among Pacific populations (Scribner et al. 2000). Populations breeding in Oregon, Washington, and Montana show very little genetic differentiation.

Nominate race: *Histrionicus histrionicus* Linnaeus.

Table 1. Management status of harlequin ducks within Partners in Flight (PIF) state Bird Conservation Plans from states within and nearby USDA Forest Service Region 2. Region 2 states are in bold.

State	Status	Citation
Colorado	Not a priority species[1]	Beidleman 2000
Kansas	State PIF plan not published[1]	
Nebraska	State PIF plan not published[1]	
South Dakota	State PIF plan not published[1]	
Wyoming	Level II priority species (monitoring suggested)[2]	Cerovski et al. 2001
Montana	Level I Priority Species[3]	Casey 2000
Idaho	Moderate Priority Species (riparian habitat)[4]	Ritter 2000

[1] = not known to breed in the state (presumed historical breeder in Colorado).

[2] = Level II species are those for which further information is needed, with monitoring suggested.

[3] = Level I species are defined as those that should receive priority conservation actions.

[4] = Moderate Priority Species are those that should be considered in habitat management and monitoring plans.

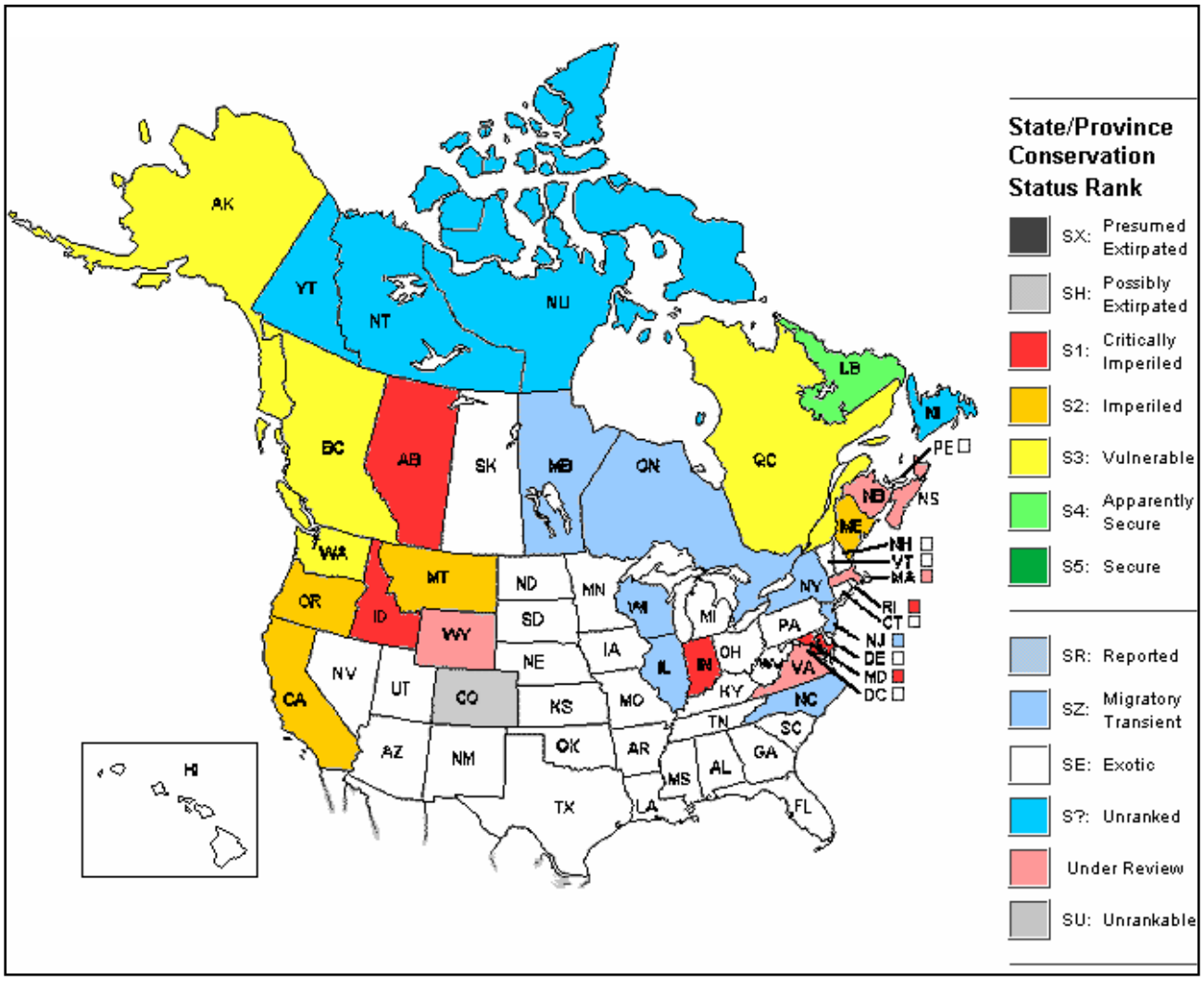


Figure 2. Status of harlequin ducks in North America, based on the Natural Heritage Program database (NatureServe Explorer 2003).

Distribution and abundance

Global perspective

Harlequin ducks breed throughout northwestern North America, as well as in disjunct areas of northeastern North America (**Figure 3**). Outside North America, they also breed in Iceland and in eastern Russia along the eastern Siberian coast. Harlequin ducks have apparently disappeared as a breeding species in Colorado (see below), in many watersheds in Idaho and Montana (Cassirer et al. 1996, Reichel et al. 1997), and in northern California (Philips 1925, Cassirer et al. 1991). A similar range collapse has likely occurred, on a larger scale, in eastern Canada where numbers underwent significant declines in the late 1900s (Robertson and Goudie 1999), but have largely stabilized in recent years (D. Esler personal communication 2004). Their wintering range is along coastal shorelines in northeastern and northwestern North America (**Figure 4**).

Regional distribution and abundance

Within USFS Region 2, harlequin ducks currently breed only in mountainous regions of northwestern Wyoming. Although there is at least one confirmed breeding record from Colorado, the species has apparently not bred in that state for at least a century (Kingery 1998). As is the case throughout their range, harlequin ducks occur at low densities in Region 2. The extent to which abundance varies annually is not clear, as there are insufficient long-term data from within Region 2. However, at Grand Teton National Park in Wyoming, numbers fluctuated between seven and 13 pairs from 1985 to 1994 (Cassirer et al. 1996).

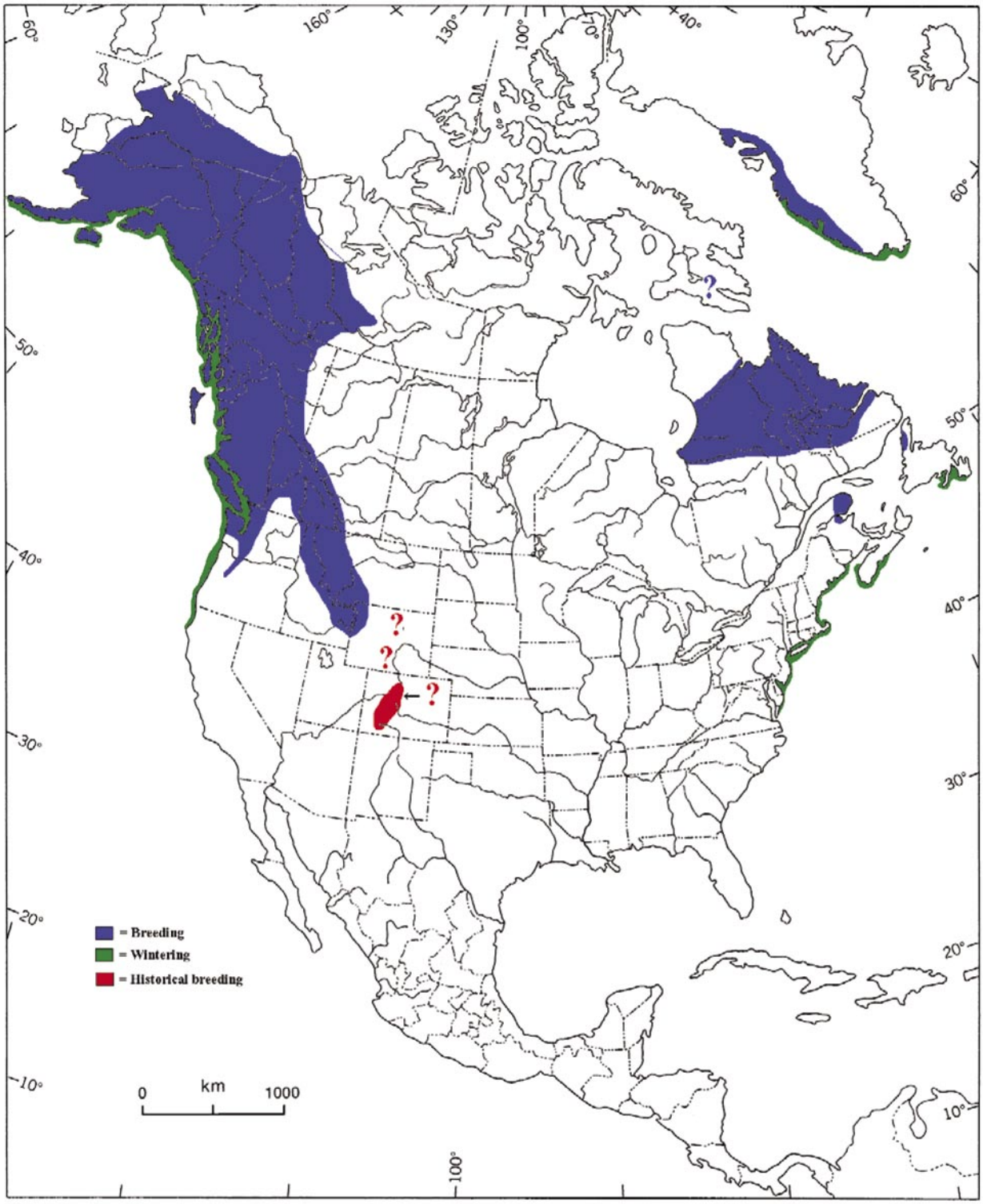
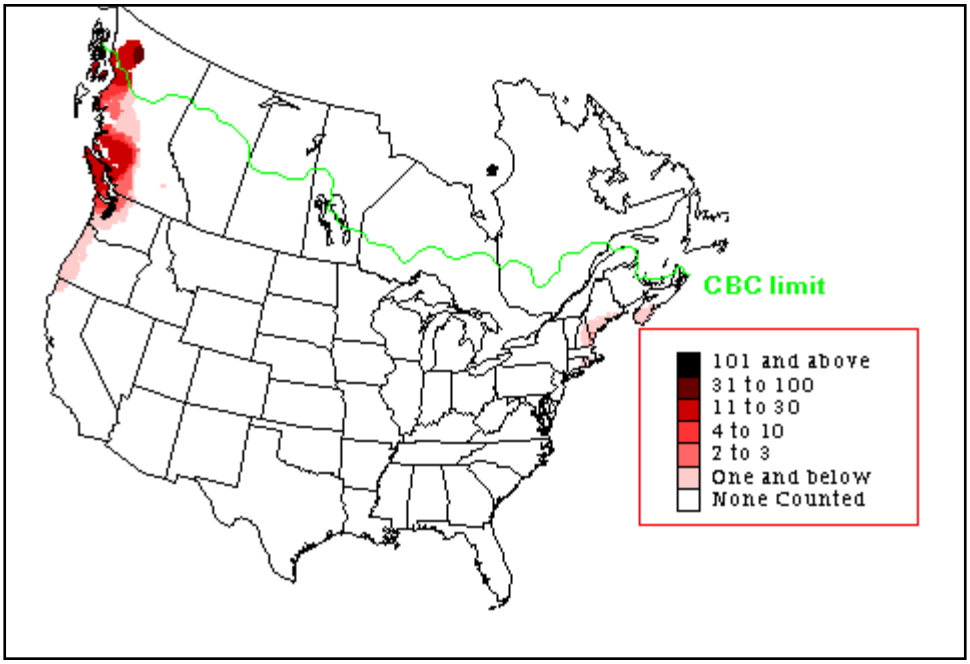


Figure 3. Current and historical ranges of harlequin ducks in North America. The figure is modified from information provided in Robertson and Goudie (1999).



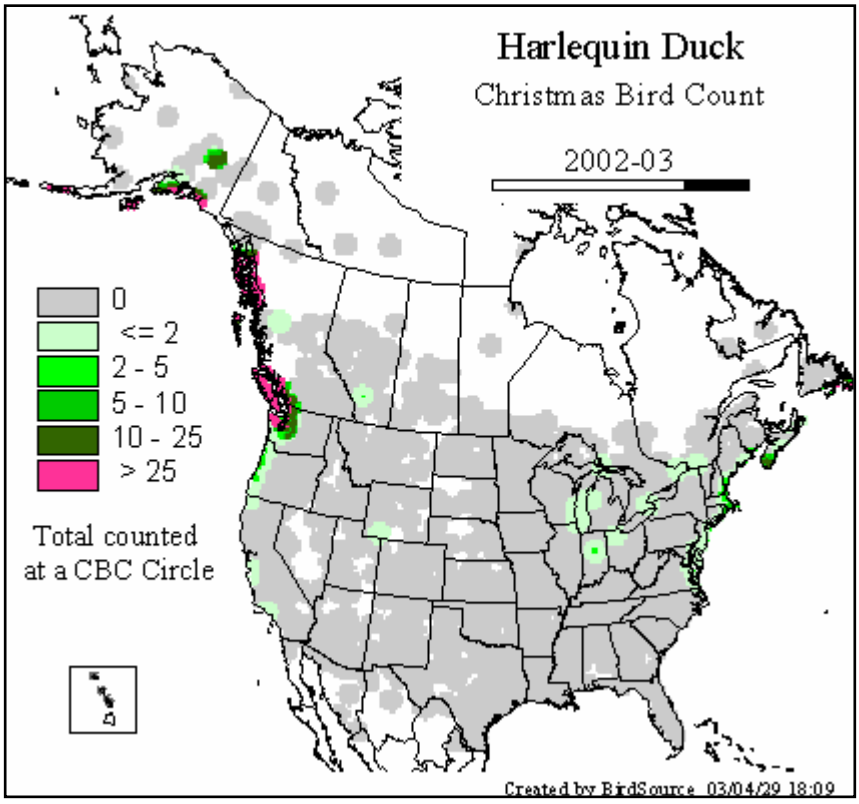


Figure 4. Winter distribution of harlequin ducks, based on North American Christmas Bird Count (CBC) data. The upper figure represents the average number harlequin ducks counted on CBCs for the period 1966 to 1996 (http://www.mbr-pwrc.usgs.gov/bbs/htm96/cbc622/ra1550.html), while the lower figure represents data from the 2002-2003 CBC (www.audubon.org/bird/cbc).

The historical and current distribution and abundance of harlequin ducks in Region 2 states are as follows:

South Dakota: Harlequin ducks are accidental in South Dakota, with only a single record of a male seen in the fall of 1995 (Tallman et al. 2002).

Wyoming: In Wyoming, harlequin ducks breed in the northwestern quarter of the state (Yellowstone and Grand Teton National Parks, Bighorn and Wind River mountains; Scott 1993) where they are considered rare (Scott 1993, Dorn and Dorn 1999). While they are regular breeders on the National Park System lands and in the Targhee, Bridger-Teton, and Shoshone national forests, their current breeding status elsewhere has not been clearly documented.

Nebraska: As in South Dakota, harlequin ducks are accidental visitors to Nebraska, with one specimen record and a handful of sight records, mostly from the late 1800s and early 1900s, and all apparently from the fall or winter (Sharpe et al. 2001). Nebraska contains no breeding habitat suitable for harlequin ducks.

Colorado: Bailey and Niedrach (1965) summarized the historical breeding records of harlequin ducks as follows: 1) Drew (1881) recorded them as breeding between 7000 and 10,000 feet but did not mention any specific records or specimens; 2) Morrison (1888) listed them as probable breeders in San Juan and La Plata counties; 3) Cooke (1897) reports records of breeding harlequins in Middle Park, Grand County, as well as along the headwaters of the Blue River in Summit County. Sclater (1912) recounted the same records, also noting that Drew's (1881) original report was from San Juan County, where they were thought to breed at high elevation. Bailey and Niedrach doubted these records, and that doubt was echoed more recently by Kingery (1998). However, Parkes and Nelson (1976) described a downy young harlequin duck in the collection of the Carnegie Museum of Natural History, collected on 15 July 1883 on Vallecito Creek, northeastern La Plata County. Thus, it appears that the early reports of a small breeding population in the San Juan Mountains of southwestern Colorado were valid. The validity of the early reports is also strengthened by a similar extirpation, and on a much wider scale, of a relatively large population of Barrow's goldeneyes (*Bucephala islandica*) from the western half of Colorado (Parkes and Nelson 1976, Potter 1998). Barrow's goldeneyes also nest at high elevation and are susceptible to contamination/degradation of the water supply and may thus have been similarly impacted by the wide-scale logging and water pollution associated with the mining boom in the late 1800s.

Kansas: Kansas contains no breeding habitat suitable for harlequin ducks. There are no early records of occurrence in Kansas (Johnston 1965, Thompson and Ely 1989), and only one recent winter record (S. Patti personal communication 2004).

According to the available historical data, there has been a retraction of the range of harlequin ducks within Region 2. The species formerly bred at least sporadically in Colorado, where breeding has not been documented since 1888. A lack of similar historical data for central and southern Wyoming precludes any analysis of changes in the species' range there, but harlequins have recently disappeared from some watersheds in Idaho and Montana (Cassirer et al. 1996).

Regional discontinuities in distribution and abundance

Within Region 2, harlequin ducks currently breed only in northwestern Wyoming. The breeding range is relatively contiguous from Yellowstone National Park and the northern Shoshone National Forest, south to the Wind River Mountain range. The available data on harlequin duck abundance in Region 2 are too few to allow for a rigorous analysis of discontinuities in abundance. The small numbers of birds that apparently breed in the Bighorn Mountains are geographically isolated from those further west, and given that harlequin ducks show extremely high breeding site fidelity, this population is likely not buffered by an influx of individuals from areas to the West.

Population trend

Harlequin ducks are a particularly difficult species to assess with respect to population trends. They are not sampled using the standard Breeding Bird Survey methodology, and thus there are no data available from that source (Sauer et al. 2003). Montevecchi et al. (1995) concluded that the eastern population (eastern Canada, northeastern United States) had declined in the 20th century, with declines continuing into the 1990s, when the total population was estimated at less than 1000 individuals. Robertson and Goudie (1999), however, suggested that (primarily based on the number of wintering birds) populations in eastern Canada and the northeastern United States were stabilizing in the 1990s.

In the western portion of the United States, Cassirer et al. (1996) made the following estimates of the number of breeding pairs:

- Washington = 399
- Oregon = 72
- Idaho = 70
- Montana = 209
- Wyoming = 58

The same authors concluded that the numbers in the U.S. Rocky Mountain have remained stable from 1989 to the mid 1990s (Cassirer et al. 1996). Harlequin duck abundance tends to increase further north in western North America. In British Columbia, wintering numbers have been estimated at 10,000 to 15,000 in the Strait of Georgia (Campbell et al. 1990, Robertson and Goudie 1999) and may have declined since 1994 (Robertson and Goudie 1999). Many more thousands of birds are presumed to winter along the coast north of the lower mainland of British Columbia, as well as on the Vancouver Island and Queen Charlotte Islands coastlines. In Alaska, wintering populations have been estimated at 18,000 in Prince William Sound (Agler and Kendall 1997), 170,000 in the Aleutian Islands (Goudie et al. 1994), and many thousands of birds along the southeastern Alaska coast (e.g., McCaffrey and Harwood 1996). Recent data from the northwestern United States suggest that populations there are stable (Cassirer et al. 1996).

Population monitoring data from Grand Teton National Park (just west of the Region 2 boundary) showed no significant trend from 1985 to 1994, with the total number of pairs varying from seven to 13 (Cassirer et al. 1996). Also, no decrease in the number of harlequin ducks has been apparent in Yellowstone National Park (also straddling the western border of Region 2), where the most recent estimate was 20 to 24 pairs, a slight increase from the 16 to 20 pairs estimated in 1997 (Oakleaf et al. 2003). Surveys conducted on the Shoshone National Forest (in Region 2) suggested at least 12 harlequin duck pairs (Laurion and Oakleaf 1995, Laurion et al. 1997, Oakleaf 1999). However, all of these authors have noted the difficulty in accurately measuring harlequin duck numbers, as adequate surveys for the species are difficult to carry out. For example, Oakleaf et al. (2003) noted that although they discovered "new" pairs of harlequin ducks on rivers and streams that had not previously been surveyed, they failed to document harlequins on a number of streams where they had been seen in previous surveys.

On the basis of surveys in the Bridger-Teton National Forest, as well as recent surveys in other areas, Oakleaf et al. (2003) estimated a statewide minimum of 70 breeding pairs in Wyoming. While the bulk of the breeding population is found in the northwestern quarter of the state (Yellowstone and Grand Teton national parks; Shoshone, Targhee, and Bridger-Teton national forests), Oakleaf et al. (2003) noted sporadic sightings and at least one confirmed breeding record along the western slope of the Bighorn Mountains. Oakleaf et al. (2003) concluded that, unless numbers have declined in areas that have not been recently surveyed, the Wyoming population appears to be stable.

As Breeding Bird Surveys do not adequately assess harlequin duck status, the species is not included in long-term analyses of those data (Sauer et al. 2003). However, because this species spends the winter at sites on or close to coastlines in the Pacific Northwest and in the Northeast, they may be adequately sampled with Christmas Bird Count (CBC) methodology (National Audubon Society 2002). Assuming that harlequin ducks breeding in the Rocky Mountains winter along the northern Pacific Coast in Oregon and Washington, then CBC data suggest that the wintering population may have experienced a long-term increase over the past 40 years (**Figure 5**; $r_s = 0.51$, $P = 0.009$). However, data from 1985 to 2003 show a statistically significant (**Figure 5**; 1985-2003 data only: $r_s = -0.75$, $P = 0.0015$) decline in the wintering population of harlequin ducks.

In summary, population trend data from dedicated harlequin duck surveys and from more general Christmas Bird Counts suggest that over the past 20 years, harlequin duck populations in Region 2 have either remained stable (evidence from breeding surveys) or have declined (evidence from winter surveys).

Activity pattern and movements

Harlequin ducks breed along inland streams and rivers with high elevation gradients. They later migrate to coastal areas where they spend the winter. In areas where breeding occurs on coastal streams, females and broods may simply move downstream to wintering sites. Birds breeding in the Rocky Mountains are thought to make relatively direct flights to coastal wintering sites, as evidenced by a female that was observed in west-central Alberta and then two days later on the coast in southwestern British Columbia (MacCallum and Cooke cited in Robertson and Goudie 1999). The majority of the Rocky Mountain breeding population is thought

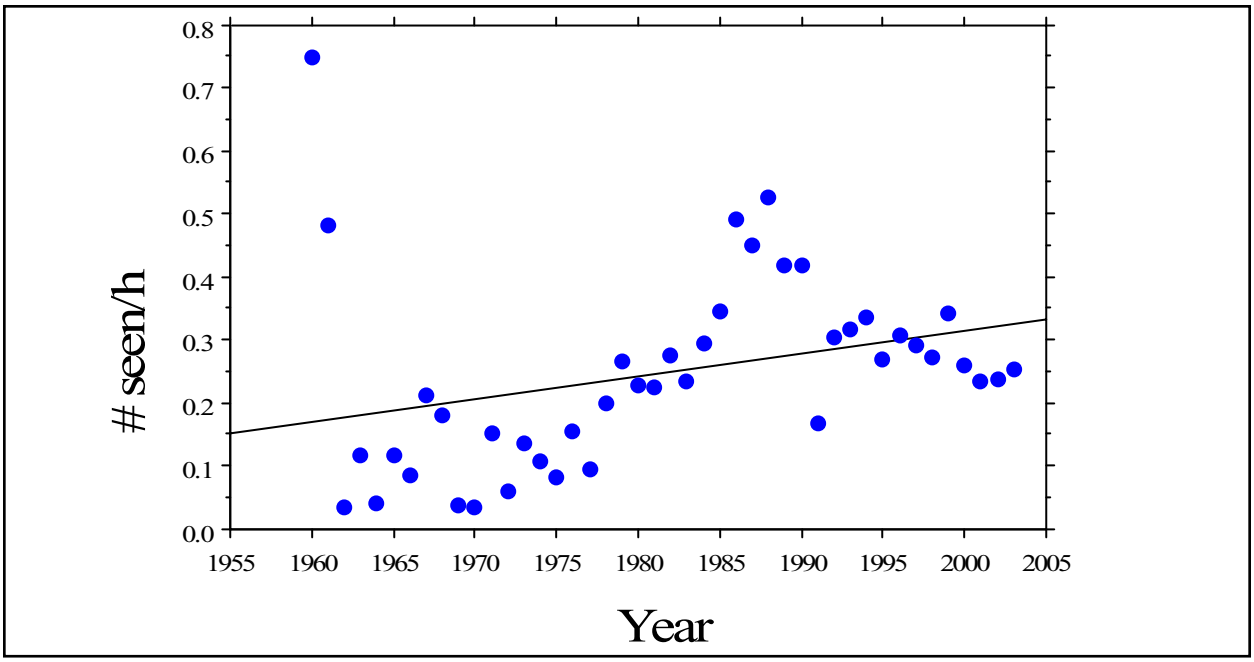


Figure 5. Temporal pattern of abundance of harlequin ducks seen on annual Christmas Bird Counts (CBC) in Oregon and Washington from 1960 to 2003. The positive overall trend (Spearman rank correlation, r_s = 0.51, P = 0.009) is largely due to the increase from 1960 to 1985, as the pattern from 1985 to 2003 showed a strong, statistically significant negative trend (r_s = - 0.75, P = 0.0015) The linear regression line is for illustrative purposes only. Data were taken from the CBC website http://www.audubon.org/bird/cbc/hr/index.html.

to winter along the coastlines of northern Washington and southern British Columbia (Cassirer and Groves 1994, Reichel et al. 1997, Robertson and Goudie 1999). Harlequins breeding in Grand Teton National Park in Wyoming, have been resighted primarily in Puget Sound, Washington, but also in the Strait of Georgia in British Columbia. In the Pacific Northwest, birds begin leaving coastal wintering sites in April, with most gone by mid-May. Arrival on the breeding grounds in Wyoming, Idaho, and Montana begins in late April.

During the breeding season, harlequin ducks forage on fast-flowing streams and rivers, either on coastal estuaries or on inland watersheds (Fournier and Bromley 1996, Hunt and Ydenberg 2000, Wright et al. 2000). Just prior to breeding, they may aggregate into small groups of two or three pairs at particularly rich feeding sites, but pairs eventually disperse to upstream breeding areas. Once incubation begins, males abandon females and move to nearby areas where they may form small "clubs" comprised mostly of males but also of immature females and females that have failed breeding. Males and females may remain in such areas for several weeks before migrating to molting/wintering areas. For birds breeding in the U.S. Rocky Mountains, the main molting areas appear to be on the wintering grounds in Puget Sound and in the Strait of Georgia (Savard 1988, Breault and Savard 1991, Wright and Clarkson 1998). Breeding females typically molt four to eight weeks later than males (Robertson et al. 1997b), and females may be accompanied by their brood during migration to the molting/wintering grounds (Regehr et al. 2001).

The most common foraging behavior is diving, but birds may also dabble at the water surface (Bengtson 1972, Robertson and Goudie 1999). Diving birds disturb the bottom surface by paddling with their feet and feed on any dislodged macro-invertebrates. Wallen (1987) measured the dive times of harlequin ducks breeding in Grand Teton National Park, and found averages of 10.3 and 11.6 seconds for males and females, respectively. During the breeding season, foraging is more intensive in the late afternoon than in the morning (Bengtson 1966, Kuchel 1977, Hunt 1998). On the wintering grounds, harlequin ducks feed almost exclusively by diving in nearshore areas, typically within 15 m of the shoreline (Goudie and Ankney 1986).

On the wintering grounds there appears to be considerable mixing of birds from different breeding areas, and this may account for considerable gene flow if males from different sub-populations follow

females to breeding streams. Given the apparent high fidelity of adult females to particular breeding streams, long distance movements of females to new breeding areas are probably rare. Similar gender differences in site fidelity occur among young harlequin ducks. For example, of 103 ducklings banded in Grand Teton National Park, five females returned to breed on or near their natal streams while no males did the same (Wallen 1991). Similarly, of 67 ducklings banded in Montana, 11 females returned to their natal stream during their second year; again, no males returned (Kuchel 1977, Ashley 1994, Reichel and Genter 1995).

Habitat

Breeding habitat

Harlequin ducks breed in coastal watersheds in the Pacific Northwest (from Oregon north to Alaska), and on inland, mountain streams and rivers. In western North America, most breeding sites are on relatively rapid streams of moderate size, typically surrounded by undisturbed forest.

Studies from throughout the North American range suggest that harlequin ducks show some regional differences in the preferred characteristics of breeding streams (Robertson and Goudie 1999). For example, preference for stream width varies from relatively narrow streams in Labrador (Rodway 1998a) to relatively wide streams in Alaska (Crowley 1994). In addition, the structure and composition of vegetation along nesting streams obviously vary from Labrador to the Rocky Mountains and the Pacific Coast. In the U.S. Rocky Mountains, vegetation along breeding streams has included willow (*Salix* spp.), immature lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*), and Douglas-fir (*Pseudotsuga menziesii*; Cassirer et al. 1996).

Breeding habitat characteristics that appear to be preferred *across the range* of harlequin ducks include:

- wide riparian vegetative zones
- clear, clean water of low acidity
- braided or multi-channel streams with islands for nesting and roosting
- rocky substrate
- a stream gradient of 1 to 7 percent, with some quiescent areas

Although there are a number of factors that appear to be important characteristics of harlequin duck breeding streams, the exact factors to which harlequin ducks are attracted when choosing breeding streams are not well understood. For example, the fact that females typically escort broods downstream after hatching suggests that food availability in the immediate nest vicinity may not be a critically important factor. Rather, proximity to a good feeding area or the availability of a high quality nest site may be more important in nest site selection. A preliminary analysis of several watershed characteristics (e.g., gradient, total area) in relation to the presence of breeding harlequin ducks in Alberta revealed no significant correlations (MacCallum et al., *in prep*.).

Cassirer et al. (1996) noted a number of factors that may act to increase the probability of harlequin ducks nesting on a particular stream, including proximity to habitat occupied by other pairs or females, the absence of human disturbance (e.g., boating, fishing), lack of access by trail or road, and good stream bank cover. Despite a number of studies that have summarized breeding stream characteristics for harlequin ducks, it is not clear whether breeding streams are chosen on the basis of food availability, or for some other reason such as protection from predators or disturbance. It is likely that some combination of those factors provides the optimal breeding stream conditions for harlequin ducks.

A model of the distribution of suitable breeding habitat for harlequin ducks in Wyoming, based upon GAP analysis, is given in **Figure 6**. The GAP habitat model provides a very good representation of the current known distribution of harlequin ducks in Wyoming (Oakleaf et al. 2003). Habitat factors associated with the presence of breeding harlequin ducks that were used when assembling the Wyoming GAP model included:

- clear rapidly flowing streams; often found with dippers (*Cinclus mexicanus*)
- mountain rivers and lakes
- streams 10 m or wider with boulder substrate and mature to old growth overstory; less frequently streams with grass/forb banks
- low gradient stream sections with braided channels
- high water quality.

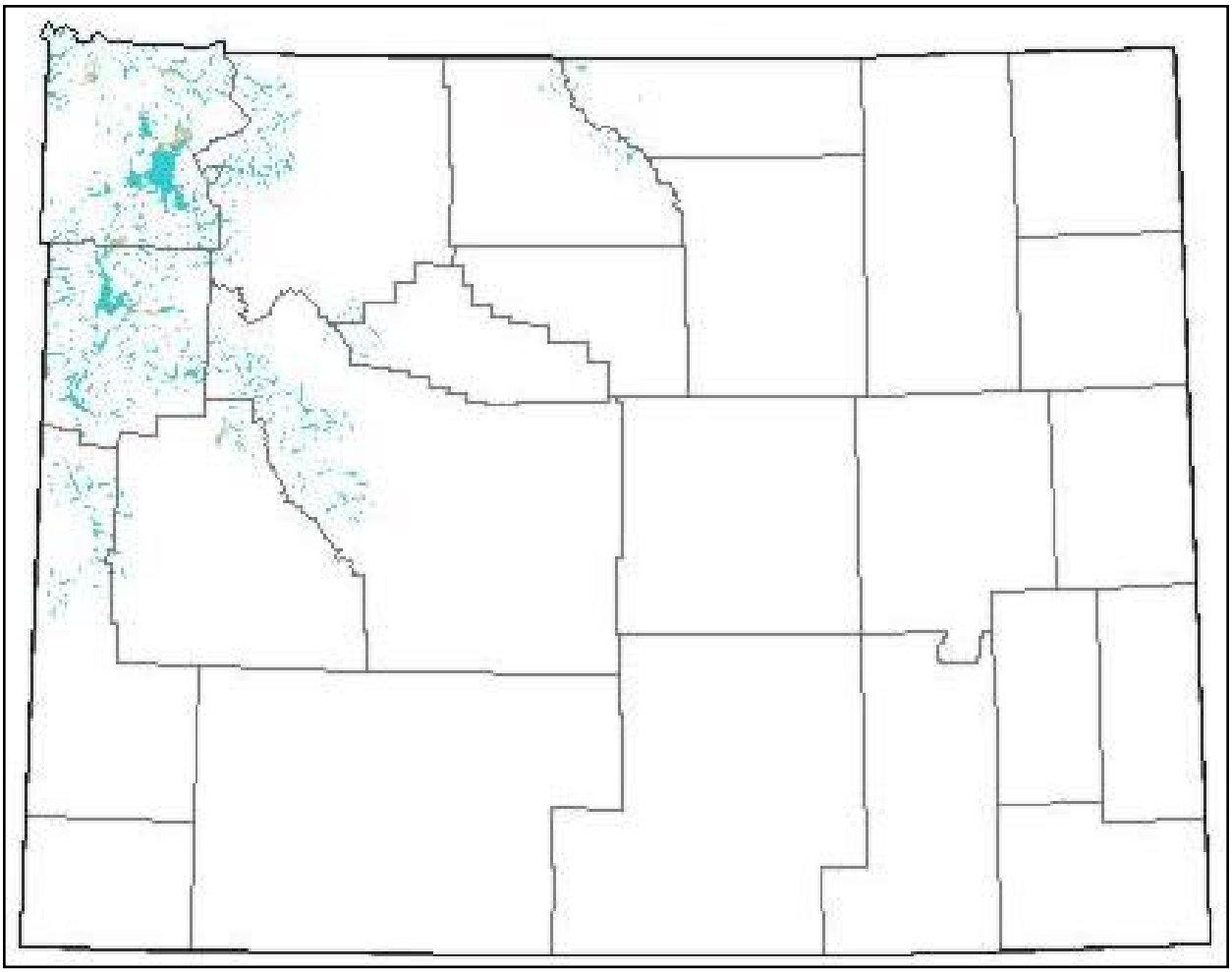


Figure 6. Modeled potential suitable habitat for harlequin ducks in Wyoming, based upon GAP analysis. Blue and beige shading represent primary and secondary habitat suitability, respectively. Habitat suitability is defined as habitats suitable for breeding, feeding, resting, and brood rearing.

Nest site habitat characteristics

Harlequin ducks typically nest on the ground in well-concealed situations and usually on mid-stream islands. Thirteen of 16 nests in Alberta were on small islands in streams (Smith 1998, 1999a). Nests are typically located close (within 10 m) to water and have some degree of vertical cover close to the nest (Bruner 1997, Robertson and Goudie 1999). Nests may also be situated at the base of trees, on piles of woody debris, under fallen logs, or on sheltered banks (Robertson and Goudie 1999). Three nest sites in Idaho and Washington included two in cavities (one at 1.8 m above ground, and one at ground level) in tree stumps, and one in a niche in a cliff, directly above the water (Cassirer et al. 1993). Whether harlequin ducks use such sites only in the absence of suitable islands or whether such sites are preferred remains unknown (F. Cassirer personal communication 2004).

Foraging habitat

During the breeding season, harlequin ducks feed on fast-flowing streams with rocky bottoms. Factors that promote a high density of benthic macro-invertebrates, such as low acidity and clear water, are important. Harlequin ducks appear to respond to annual and seasonal changes in insect abundance; they may congregate, just before or just after breeding, at sites where invertebrate prey density is high, such as at lake outlets and stream confluences (Larson and Colbo 1983). Streams that harbor healthy populations of fish, particularly salmonids and catostomids, are also favored foraging sites (Smith 1997, Hunt 1998), either because of the presence of fish roe as food, or because of correlations between fish presence, water quality, and insect abundance (or both). In Iceland, preferred foraging areas were in water less than 0.8 m deep (Bengtson 1972).

During winter, harlequin ducks feed nearshore along rocky coastlines. Vermeer (1983) found that preferred winter prey occurred primarily on rocky and gravel substrates close to shore. Preferred water depths are less than 10 m, and in Washington, harlequin ducks typically feed in water 1 to 2 meters deep, often over eelgrass (*Zostera* spp.; Hirsch 1980, Robertson and Goudie 1999). Submerged mussel beds sometimes attract large numbers of harlequins (Patten et al. 1998).

Food habits

The diet of harlequin ducks is comprised entirely of animals, typically macro-invertebrate larvae during the summer and a variety of marine invertebrates during the winter. In a food habits study of harlequins across North America, Cottam (1939) found the following food items (percent volume): crustaceans (57), mollusks (25), insects (10), echinoderms (2), and fish (2). Although characterized as a year-round diet, the results of this study likely reflect the winter diet for harlequin ducks. During the breeding season, the diet consists mostly of insects and fish roe (Dzinbal and Jarvis 1984). During the summer in Iceland, midge (Simuliidae) larvae are the primary food item; these are also important to harlequins in northern Labrador in August (Rodway 1998b). In the Rocky Mountains (Idaho and Wyoming), the primary foods are aquatic larvae including midges (Chironomidae), caddisflies (Trichoptera), stoneflies (Plecoptera) and mayflies (Ephemeroptera; Wallen 1987, Cassirer and Groves 1994). In most areas, ducklings appear to consume a diet similar to that of adults (Bengtson 1972, Robertson and Goudie 1999). Aside from the casual observations described above, there have been no quantitative studies of diet during the breeding season, except for Bengtson's (1972) study in Iceland, where over 96 percent of food for adults and ducklings was Simuliid midge larvae.

During the winter, harlequin ducks feed largely on inshore marine invertebrates including snails, periwinkles, blue mussels, small clams, hermit crabs, shrimps, and amphipods (Vermeer 1983, Goudie and Ankney 1986, Rodway and Cooke 2002). Harlequins are adept at feeding on limpets and chitons that are strongly attached to rocks.

Breeding biology

Courtship and pair formation

Harlequin ducks begin forming pair bonds on the wintering grounds, with established pairs re-uniting as early as October, and new pairs forming later the following spring (Gowans et al. 1997, Robertson et al. 1998, Torres et al. 2002). Typical behavior during courtship and pair bond establishment consists of "head-nodding" by both males and females (Inglis et al. 1989, Gowans et al. 1997). Unpaired males may "rush" (rapidly approach with head low and wings outstretched) paired females and head-nod towards paired males (Robertson and Goudie 1999).

Harlequin ducks maintain pair bonds for long periods. Although the pair bond temporarily dissolves during the incubation period, the sexes re-unite four to six months later on the wintering grounds. Typically, the pair bond is maintained until one of the pair members dies (Smith et al. 2000), with pairs remaining together even after failed breeding attempts (Robertson 1997).

Clutch and brood size

Harlequin ducks typically lay a single clutch per season, and it is not known whether replacement clutches are laid if the first clutch/brood is lost (Robertson and Goudie 1999). Clutch size has been reported as follows: Alaska, 6.1 (± 0.9 SD, n = 7; Crowley 1999); Alberta, 6.1 (n = 9; Robertson and Goudie 1999); Oregon, 5.2 (± 1.2 SD, n = 21; Bruner 1997); Iceland, 5.7 (n = 77; Bengtson 1972). Studies in Iceland suggest that clutch size normally declines over the course of the breeding season (Bengtson 1972).

Ducklings are precocial at hatching, with all young apparently hatching within a 24 to 48 hour period, and leaving the nest shortly thereafter. Young are able to feed immediately after hatching but do not dive regularly for several weeks (Kuchel 1977). Cassirer et al. (1996) reported a range of 2.6 to 4.5 young per brood at fledging (among successful nesters).

Parental care and offspring behavior

Female harlequin ducks perform all of the incubation of the eggs, as well as the brooding and protection of the hatchlings; males provide no paternal care. During the incubation period, females spend considerable periods of the day incubating, typically leaving the nest for only a brief period each evening to feed and preen (Bengtson 1972, Smith 1997, Hunt 1998, Wright 1998). The female typically covers the eggs with down when she leaves the nest. Females sit tightly when incubating, allowing very close approach of humans. The only data on the length of the incubation period come from Iceland (Bengtson 1972), where incubation lasted a mean of 28 days (27 to 29 days, n = 4).

The only available data on the growth of hatchlings showed that 22 to 27 day old young gained an average of 66 grams in mass over a 10-day period (Smith cited in Robertson and Goudie 1999). Females lead the ducklings to relatively quiescent areas of streams and rivers, where food is more easily available for the foraging ducklings (Robertson and Goudie 1999).

Estimates of the age at which ducklings fledge has varied considerably, with estimates ranging from 42 (Wallen 1987) to 56 days (Kuchel 1977) after hatching. There is considerable variability in the timing of brood abandonment by females, with some females leaving when the young are less than 2 weeks old, and others after the young are capable of flight (Hendricks and Reichel 1998). Regehr et al. (2001) have found that females in the Canadian Rocky Mountains may accompany their broods to the wintering grounds.

Timing of breeding and breeding success

In Region 2, harlequin ducks breed relatively late, with a mean hatching date of 31 July in Grand Teton National Park (**Table 2**; Wallen 1987). However, given that the timing of breeding can vary widely among years, further data from Wyoming would help to clarify the normal timing of breeding within Region 2. At least within Alberta (Hunt 1998), and probably range-wide, harlequin ducks breed later at higher altitudes.

Hatching success appears to be relatively high, ranging from 87 to 97 percent of all eggs laid (**Table 3**), to 74 percent of all clutches hatching at least one egg in another study (Bruner 1997). Fledging success (percent of hatched young that successfully left the breeding stream) may vary widely among years, with reported rates varying between 13 and 83 percent (**Table 3**). However, it should be noted that these estimates of reproductive success are likely overestimates due to the difficulty in tracking pairs that fail early and thus go undetected. There have been no analyses of seasonal trends in breeding success (likely from a lack of sufficient data). There are no published data on lifetime reproductive success, but in Idaho, it is thought that within each cohort, a few high quality females produce a disproportionately large number of young (F. Cassirer cited in Robertson and Goudie 1997).

Demography

Genetic characteristics and concerns

The North American population of harlequin ducks is widely separated into eastern and western sub-populations. While there is some evidence of genetic differentiation among three geographically separated breeding populations in the eastern portion of the range (Robertson and Goudie 1999, Scribner et al. 2000), populations in Oregon, Washington, and Montana show relatively few genetic differences (Brown 1998). The latter result suggests either significant gene flow among harlequin ducks in the northwestern United States, or a relatively recent range expansion into that area, and thus insufficient time for genetic differentiation to have occurred. The extent to

Table 2. Mean hatching dates of harlequin duck clutches within North America.

Study area	n	Mean hatch date	Range	Citation
Wyoming (Grand Teton National Park)	15	31 July	5 July to 6 August	Wallen 1987
Northern Idaho	12	18 June	15 June to 1 July	Cassirer and Groves 1994
Oregon	16	24 May to 25 June	Bruner 1997	Bruner 1997
West-central Alberta (Jasper National Park)	4, 10, 5	15 July, 25 July, 4 August (over 3 years)	—	Hunt 1998
West-central Alberta	9, 9	12 July, 11 July (over 2 years)	4 to 18 July, 1 to 23 July	MacCallum and Bugera 1998, MacCallum unpubl, cited in Robertson and Goudie 1999
Southwestern Alberta (Banff National Park)	22	12 July	27 June to 22 July	Smith 1999a
Southwestern Alberta	6	7 July	3 to 17 July	Smith 1999b
Alaska	8	—	3 to 15 July	Dzinbal 1982
Northern Labrador	6	—	22-31 July	Rodway et al. 1998
Northern Newfoundland	6, 15	—	9 to 19 July, 3 to 30 June	Goudie 1998

Table 3. Hatching and fledging success of harlequin ducks in North America.

Study area	Hatching success (n = # eggs)	Fledging success (n = ducklings)	Citation
Montana (3 years)	—	18%, 40%, 83%	Smith 1999a
Idaho	—	55% (60)	Cassirer et al. 1996
Oregon	—	60% (68)	Bruner 1997
Alberta	87% (54)	13% (23)	Smith 1998
Alaska	97% (32)	43% (60 broods)	Crowley 1999

which the population breeding in Region 2 is isolated from those further north is not known, but a more or less continuous distribution of breeding birds from the western edge of Region 2 (the Shoshone National Forest) through northwestern Wyoming and into eastern Idaho suggests that the Region 2 population is not isolated from those to the northwest.

Several studies have reported high breeding site fidelity among adult harlequin ducks (**Table 4**). However, almost all banded ducklings that have been recovered later on the breeding grounds have been females (Cassirer et al. 1996, Robertson and Goudie 1999), suggesting that juvenile males may be moving moderate to long distances from their natal sites. Thus, the principal agent of gene flow among geographically separated harlequin ducks appears to be natal dispersal of males.

It is important to note that harlequin ducks pair on the wintering grounds, and as a consequence, genetic exchange among sub-populations would most likely occur as a result of high fidelity to wintering areas among females and their broods (Cooke et al. 2000, Robertson et al. 2000). Currently, there is still insufficient information available on any demographic sub-structuring within western harlequin duck populations to allow us to define conservation units. The most likely sources of such information will come from studies of the breeding, migratory, and wintering ecology of populations breeding in interior mountains, coastal mountains, and along low-elevation coastlines (i.e., the most likely divisions of populations in terms of ecological divergence).

Life history characteristics

Harlequin ducks exhibit delayed breeding, with males and females typically not breeding until they are at least three years old. Although some females attempt to breed when they are two years old, they are rarely successful and do not typically reproduce successfully until they are at least five years old (Reichel et al. 1997). Similarly, two-year-old males sometimes acquire a mate, but males rarely breed until they are at least three years old. Observations of loafing females during the summer have led to the conclusion that some females may skip breeding (e.g., Robertson and Goudie 1999, Hunt and Ydenberg 2000). However, the lack of observations of individually-marked birds makes it difficult to distinguish between failed breeders, young birds, and birds that may be skipping a breeding attempt. Data on the body mass of non-breeding females in Alberta show that they do not gain body mass seasonally, as breeding females do; this suggests that such birds are either young birds or birds that have skipped breeding (see Figure 5 in Hunt and Ydenberg 2000). The primary factor regulating the percentage of females that loaf throughout the summer is thought to be variation in food abundance, with more loafers during poor food years (Bengtson and Ulfstrand 1971, Robertson and Goudie 1999). Estimates (based primarily upon sightings of loafing females during early summer) of the percentage of females that did not breed have ranged from 14 to 89

Table 4. Return rates of marked adult harlequin ducks to breeding streams in North America.

Study area	% adults returning (n)	% adult females returning (n)	% adults males returning (n)	Citation
Wyoming	52% (38)	—	—	Wallen 1987
Montana	—	56% (53)	53% (39)	Reichel et al. 1997
Montana	—	100% (6)	67% (6)	Kuchel 1977
Idaho	63% (31)	—	—	Cassirer et al. 1996
Alberta	—	67% (18)	58% (36)	Smith 1996
British Columbia	—	18% (11)	—	Robertson and Goudie 1999
Alaska	—	44% (16)	29% (7)	Crowley 1994

percent (**Table 5**). Observations of individually-marked birds are clearly needed in order to confirm whether females are actually skipping breeding in some years, or whether loafing females are the result of early failures during the reproductive cycle.

Adult survival has been measured in a number of studies, with male survival averaging 86 percent (in winter) in southwestern British Columbia (Robertson and Goudie 1999) and 86 percent (based on resightings in spring) in southwestern Alberta (Smith 1998). Female survival averaged 77 percent during winter in Alaska (D. Esler cited in Robertson and Goudie 1999), 82 percent during summer in Oregon (Bruner 1997), 77 percent during winter in southwestern British Columbia (F. Cooke cited in Robertson and Goudie 1999), and 78 percent in southwestern Alberta (based on resightings in spring and summer; Smith 1998). Survival of recently hatched ducklings to the fledging stage has been measured in a number of studies and varies widely among sites and years (**Table 3**). Unfortunately, there have been few studies of the survival of young harlequin ducks over their first or second years. Of 103 ducklings banded in Grand Teton National Park in Wyoming, five females returned to breed on or near their natal streams (Wallen 1991). Eleven of 67 banded ducklings in Montana returned to their natal stream during the following breeding season (Kuchel 1976, Ashley 1994, Reichel and Genter 1995). In both of these studies, all of the returning birds were females (Cassirer et al. 1996).

Demographic analyses of harlequin duck population viability were carried out by Goudie et al. (1994). Given that adult survival is relatively high and that reproductive success is highly variable, especially for young females, it is not surprising that the results of the demographic modeling showed that population growth rates are most sensitive to variation in adult survival rates. Breeding success is low until males and females reach approximately five years of age (Reichel et al. 1997). Consequently, older ducks are responsible for a majority of the annual production of fledglings. The high annual variation in reproductive success, likely due to failed breeding attempts, also contributes significantly to the population demographic models.

Social patterns and spacing

Harlequin ducks are highly social in the non-breeding season, forming small groups and roosting offshore at night (Robertson and Goudie 1999). During the early breeding season, a few pairs may congregate at pre-nesting foraging areas, with the male and female later dispersing to the breeding site where they remain until the male abandons the female at the start of incubation (Bengtson 1966, Inglis et al. 1989). There has been little study of territorial behavior during the breeding season, likely because pairs breed at such widely separated sites and thus rarely come in contact. However, there is no evidence of territorial behavior among breeding adults (Inglis et al. 1989, Robertson et al. 2000).

Factors limiting population growth

The factors limiting population growth in harlequin ducks are not well understood, but they are likely some combination of the following:

Life-history traits: Harlequin ducks are relatively long-lived, with low reproductive output, high breeding site fidelity, and delayed reproduction. All of these traits may limit the extent to which harlequin duck populations are able to rebound from population declines. The survival of adult females is likely the most critical factor in maintaining local populations.

Habitat degradation: Studies in British Columbia showed higher breeding densities of harlequin ducks in areas where timber had not been harvested (Freeman and Goudie 1998). Logging has also been cited as the main source of breeding habitat degradation in coastal British Columbia (Breault and Savard 1991).

Table 5. Annual percentage of female harlequin ducks that either fail early in the breeding season (and do not re-nest) or skip breeding. Percentages are based on the number of females seen loafing in the study area during the early and middle portions of the breeding season.

Study area	Years of study	% of females not breeding	Citation
Pacific Northwest	—	53-66%	Summary in Robertson and Goudie 1999
Alaska	2, 2	14-26	Crowley 1999
Alaska	1	47-59%	Dzinbal 1982
Oregon	1	51%	Bruner 1997
Alberta	5	17%	C. Smith cited in Robertson and Goudie 1999

Predation: Robertson and Goudie (1999) suggest that predation on nesting females and ducklings by raptors and mustelids is an important source of mortality in some areas. Heath (2001) suggested that harlequin ducks in Labrador bred in areas that were relatively free from nesting raptors and that such spatial segregation occurred at the landscape and the home-range scales.

Spatial and temporal variation in food abundance: Although studied closely only in Iceland, the long-term data from there suggests that annual and spatial variation in reproductive success is largely a result of variable food supplies. As harlequin ducks in the Rocky Mountains feed on a relatively specialized food resource (benthic macro-invertebrates along rocky stream bottoms), any disturbance to natural water flow patterns or water clarity, acidification, heavy metal pollution, or sedimentation could significantly affect food availability and increase the number of birds that fail to breed. In addition, the introduction of fish may also reduce local invertebrate prey abundance. Consequently, forest management activities, such as logging, mining, and road building, are often cited as potential contributors to stream degradation. However, the link between these factors and harlequin duck breeding success warrants further study.

Hunting: Although there are no data on the number of harlequin ducks taken by hunters along the Pacific Coast (the primary wintering area for Region 2 birds), the species' tame behavior and nearshore foraging and roosting make them relatively easy targets for hunters. Cassirer et al. (1996) noted that attempts to conserve harlequin ducks on the breeding grounds may be undermined if hunting pressure is not decreased or eliminated on the wintering grounds.

Pollution: Because the Rocky Mountain population of harlequin ducks winters in a relatively small area in Puget Sound and the Strait of Georgia, an oil spill in that area could have catastrophic effects on the population viability of harlequin ducks in Region 2. The oil spill in Prince William Sound, Alaska directly killed over 1300 harlequin ducks and left others with various stages of internal contaminant accumulation. Although the longer-term effects on the local harlequin duck breeding population are controversial (see references in Robertson and Goudie 1999), such an event in the Puget Sound-Georgia Strait region could potentially eliminate the Region 2 population of harlequin ducks. Thus, contamination of nearshore waters on the wintering grounds is a potential significant factor limiting population growth.

As mentioned above under food abundance, pollution (e.g., acidification, heavy metal concentrations) of mountain streams and rivers has been cited as a factor affecting the breeding success of harlequin ducks and has been cited as a probable cause of the extirpation of the species in the southern Rocky Mountains (Sclater 1912, Bailey and Niedrach 1965). Although there is a lack of hard correlative evidence for such an effect, the boom in mining activity in the mountains of Colorado coincided with the apparent extirpation of harlequin ducks.

Community ecology

Interactions between harlequin ducks and their predators, competitors, and habitat are shown in **Figure 7**. Historically, the primary factor affecting harlequin duck distribution and abundance in Region 2 was likely the availability of clean, fast-flowing, undisturbed streams and rivers with high elevation gradients. Such habitat provided suitable nesting sites, as well as brood rearing areas for harlequin ducks. Potential threats to the quality of these breeding areas included logging, mining, road building, livestock grazing, and human recreation. Currently, the extent to which these factors continue to affect the quality of potential breeding streams in Region 2 is unclear; there are many streams/rivers in Region 2 that appear to be suitable breeding habitat but are not used by harlequin ducks. The habit of congregating in flocks along nearshore coastlines in winter renders harlequin ducks susceptible to hunting pressure and to potential mortality due to oil spills or other sources of marine pollution.

Known or presumed predators of harlequin ducks include bald eagles (*Haliaeetus leucocephalus*), hawks (*Buteo* spp.), great horned owls (*Bubo virginianus*), seals, and river otters (*Lontra canadensis*; Robertson and Goudie 1999). Nesting females and eggs have been taken by mink (*Mustela vison*) and marten (*Martes americana*; Kuchel 1977, Bruner 1997, C. Smith cited in Robertson and Goudie 1999). Known egg predators include common ravens (*Corvus corax*), mink, arctic fox (*Alopex lagopus*), and red squirrels (*Tamiasciurus hudsonicus*; Robertson and Goudie 1999).

Harlequin ducks may compete for food with other sea ducks during the winter (Robertson and Goudie 1999), but there is little evidence of aggression when feeding in mixed species flocks. The only potential competitor for food on the breeding grounds in Region 2 is likely the American dipper (*Cinclus mexicanus*), which also feeds on benthic invertebrates. However,

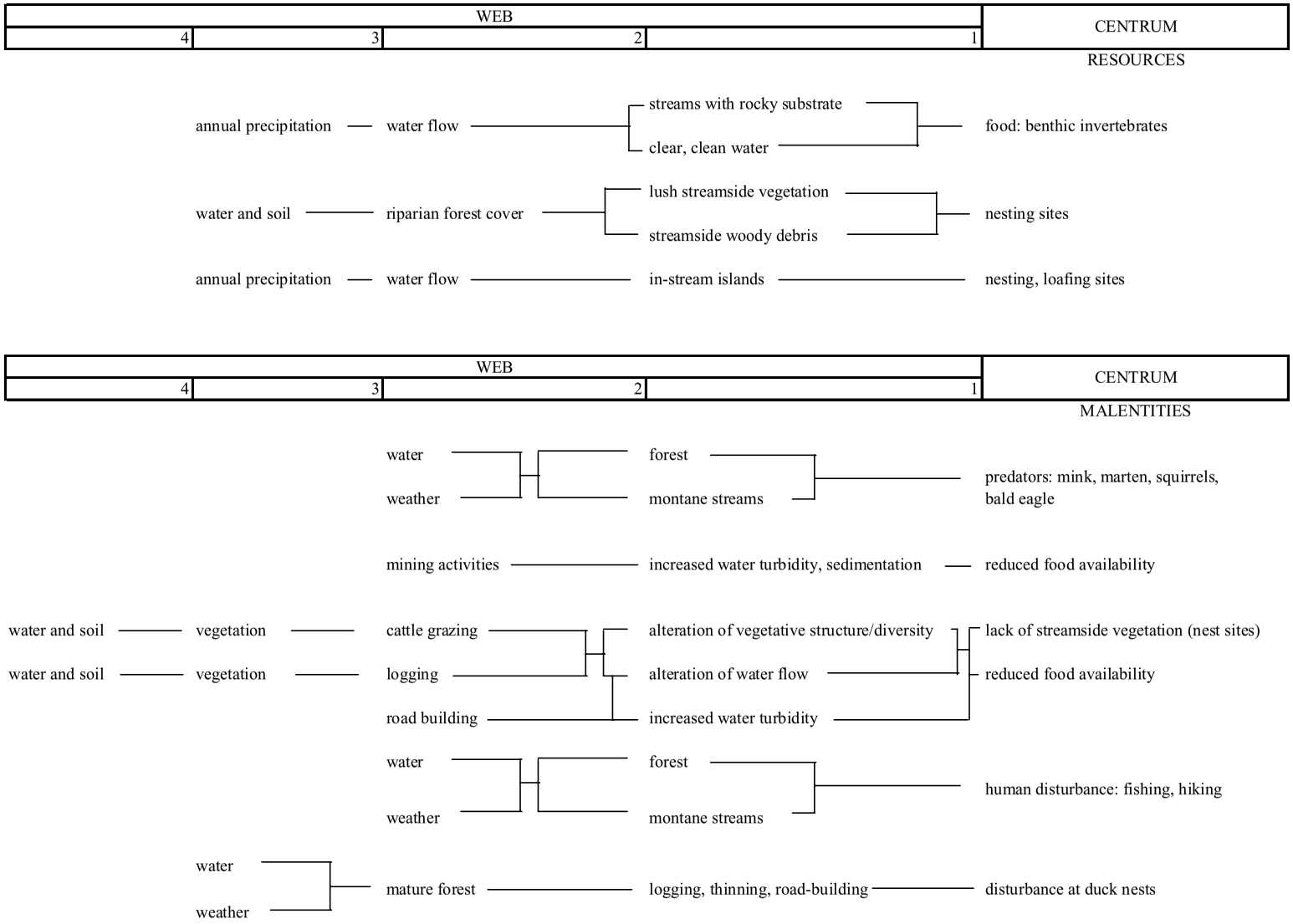


Figure 7. Envirogram representing the web of linkages between harlequin ducks and the ecosystem in which they occur.

there are no observations of aggressive interactions between these two species.

Harlequin ducks apparently carry lighter parasite loads than do other sea ducks (Robertson and Goudie 1999). Parasites include trematodes, cestodes, acanthocephalan worms, and feather lice (Mallophaga).

CONSERVATION

Threats

Within Region 2, harlequin ducks are primarily threatened by two factors – disturbance to females at breeding sites and degradation of water quality within rivers and streams. Thus, regulating the activities of humans along mountain rivers and streams from May to July, as well as adopting forest management practices (e.g., avoidance of logging and mining near riparian areas) that maintain the integrity of riparian systems are keys to ensuring population viability of harlequin ducks. However, probably the greatest potential threat to the Region 2 population of harlequin ducks is their vulnerability to any oil or chemical spill on their wintering grounds in the Pacific Northwest. Recent summaries of long-term effects of the Exxon Valdez oil spill in Alaska have shown continued negative effects of the spill on the survival of harlequins, nine years after the event (Esler et al. 2000, Esler et al. 2002). As the Region 2 population of harlequin ducks is relatively small, such an event in the Puget Sound/Georgia Strait area of Washington/British Columbia would pose a serious threat to this population.

The major threats to harlequin duck populations are summarized below.

Human recreational disturbance

There is correlative evidence supporting the negative effects of human disturbance on harlequin duck reproductive success. Within Region 2, Scott (1993) noted that harlequin ducks abandoned an historical breeding site (LeHardy Rapids) in Yellowstone National Park after a boardwalk was built to facilitate human access to the area. There are several other reports of harlequin ducks abandoning breeding sites that became subject to repeated human disturbance (see Cassirer and Groves 1991, Clarkson 1992, 1994, Hunt 1998). Disturbance may include humans walking along shorelines (Scott 1993) or fishing (Wallen 1987), boating activities (largely a problem on staging and wintering areas; Smith 1996b), and river rafting (Hunt 1998). Aside from direct abandonment in response to disturbance, females may attempt to move the brood to undisturbed areas (Kuchel 1977, Wallen 1987). Although most of these studies lack proper statistical controls (e.g., comparison to undisturbed "control" sites), the available evidence suggests that harlequin ducks are likely to abandon sites that receive heavy human disturbance.

Harlequin ducks are also relatively sensitive to the activity of researchers and do not tolerate some research methods. During research on nesting harlequin ducks, C. Smith (cited in Robertson and Goudie 1999) flushed seven incubating females, and although there were no subsequent cases of nest abandonment, the females remained off the nest for several hours. Satellite telemetry (using implanted transmitters; Esler et al. 2000) has been successfully employed (Robertson and Goudie 1999). However, harlequin ducks do not react well to backpack-mounted transmitters (Robertson and Goudie 1999), and patagial tags have been shown to cause lowered reproductive success (Dzinbal 1982).

Hunting

Hunting has been implicated in the decline of the eastern population of harlequin ducks, where migrating and wintering birds are easily shot at near-shore sites (Palmer 1949, Goudie 1989). Montevecchi et al. (1995) summarized the problem within the eastern range (Labrador, Newfoundland, Quebec, Greenland), where hunting was outlawed in 1991. Despite the ban, hunting has continued in that area (Montevecchi et al. 1995), perhaps because of the drab plumage of females and young birds, which renders them difficult to identify and thus more likely to be shot by hunters. Robertson and Goudie (1999) reviewed the current hunting pressures in the Pacific Northwest where harlequin ducks are under "moderate" hunting pressure in Washington, "low" pressure in British Columbia, and variable pressure in Alaska. Overall, the available information was not sufficient to assess whether hunting is currently posing a threat to western populations. Nonetheless, given the long lifespan, low reproductive rate, and delayed breeding in harlequin ducks, even a low level of hunting pressure is likely to have a significant impact on population stability in the western United States.

Logging

Logging and associated activities such as road-building may lead to a number of potential problems for harlequin duck habitats. First, intensive logging often leads to increased runoff and altered water flow, both of which may have negative consequences for harlequin

duck breeding success (Cassirer et al. 1996). Second, runoff from logged areas and from logging roads increases sedimentation and turbidity in streams, and may thus decrease prey availability. Logging and road-building activities near streams may also lead to direct disturbance of nesting birds. However, as with several other presumed threats to harlequin duck habitat quality, the effects of logging and road-building activities deserve closer study as they have not yet been carefully quantified in the field (see the Information Needs section below; see also MacCallum et al., *in prep*.).

Mining activities

Although no direct evidence has been cited implicating mining activities as a cause of harlequin ducks abandoning breeding streams, concern has been expressed (e.g., Cassirer et al. 1996) that such activities will lead to increased sedimentation and acidification, altered water runoff, and injection of toxic heavy metals into the aquatic system. Given the sensitivity of harlequin ducks to water quality of the breeding streams (Robertson and Goudie 1999), efforts should be made to buffer any streams from the potential chemical and physical effects of mining activity. Analysis of the correlation between mining activity and the use of streams by harlequin ducks is currently underway in Alberta (MacCallum et al., *in prep*.).

The disappearance of harlequin ducks as a breeding species in Colorado may have been due (in part) to intensive mining activities along mountain streams in central and western Colorado during the late 1800s (e.g., Digerness et al. 1982). It is important to note that logging was also widespread and relatively intense during the same period and may have acted in concert with mining activities to degrade harlequin duck breeding streams in Colorado. Currently, pollution from mining activities continues to be a problem in Colorado and Wyoming, with some instances (e.g., Summitville Mining Corporation pollution of the Alamosa River; see for example http://www.atsdr.cdc.gov/HAC/PHA/summit/sum_p1.html) of large-scale, catastrophic effects on riverine flora and fauna.

Pollution

Contamination by pollutants is a problem for harlequin ducks on the wintering grounds. The majority of Region 2 harlequin ducks likely winter in the Puget Sound area and north into the Strait of Georgia. This area is a particularly busy shipping lane, and harlequin ducks are therefore susceptible not only to occasional small discharges of bilge and other forms of pollution, but also to a catastrophic pollution event such as the Exxon Valdez oil spill. Near-shore oil spills are a particular problem for harlequin ducks. Nine years after the Exxon Valdez oil spill in Alaska, wintering harlequin ducks were still showing decreased survival in areas affected by oil (relative to harlequins in unaffected areas; Esler et al. 2000, Esler et al. 2002).

Fischer (1998) also reports high levels of carcinogenic hydrocarbons (from creosote in piers or from diesel soot) in wintering harlequin ducks in Alaska. Bioaccumulation of heavy metals has been cited as a problem for all sea ducks (Henny et al. 1995). Harlequin ducks tend to congregate in winter at favored wintering sites and are thus particularly susceptible to pollution/contamination on the wintering grounds.

Livestock grazing

Livestock grazing is a common practice on National Forest System lands in the West and may represent a threat to harlequin duck nesting habitat. Grazing livestock often trample streamside vegetation that would provide critical cover to nesting harlequin ducks. In addition, livestock grazing often leads to increased runoff and increased sedimentation, both of which may lower harlequin duck reproductive success (Cassirer et al. 1996, Robertson and Goudie 1999). Finally, in areas with heavy livestock grazing, livestock may directly disturb nesting activities of female harlequin ducks.

Conservation Status of Harlequin Ducks in Region 2

Unlike most other species of North American birds, there are no data available from Breeding Bird Surveys with which to assess long-term trends in harlequin duck population status. In this report, CBC data were used to assess population changes on the (presumed) main wintering grounds, in Oregon and Washington (**Figure 5**). Data from those counts are difficult to interpret. Although overall harlequin duck numbers have risen in those areas since the collection of CBC data began in 1960, some measure of increase is expected given the increase in the number of counts along the coast, as well as the increased sophistication of counters. Of more concern are the most recent CBC data from 1985 to 2003, which show a significant negative trend (**Figure 5**). The most recent statewide estimate was of 70 breeding pairs of harlequin ducks in Wyoming (Oakleaf et al. 2003), which is comparable to the previous estimate of 58 pairs by Cassirer et al. (1996), given that Oakleaf et al. (2003) surveyed

areas that had not been included in the previous work. However, as mentioned previously, the difficulty in accurately surveying for harlequin ducks leaves a degree of uncertainty over the current population numbers in Wyoming.

The apparent loss of the small breeding population in Colorado in the late 1800s is difficult to understand. Although there has been considerable debate over the accuracy of the early breeding reports, Parkes and Nelson (1976) discovered a downy young harlequin from La Plata County. This, along with a few other scattered reports of breeding in southwestern and central Colorado (see Bailey and Niedrach 1965, Andrews and Righter 1992), suggest that there was at least sporadic breeding in the mountains of Colorado. The reasons for the extirpation of harlequin ducks in Colorado remain unknown. However, extensive mining in Colorado during the late 1800s may have led to the degradation of many of the high altitude streams that harlequin ducks used for breeding through siltation, pollution, and watershed deforestation. In addition, human activities in association with mining activities along these streams may have contributed to failed reproductive success.

Currently, the total breeding population of harlequin ducks in Region 2 appears to be less than 20 pairs. All of the known breeding sites are within the Shoshone (12 pairs) and Bighorn national forests in Wyoming. These forests are on the southeastern periphery of the species' current range, and because harlequin ducks show relatively strong breeding site fidelity, there may be little hope for recovery of these populations if they become extirpated. Consequently, annual surveys for harlequin ducks on these two forests should be carried out to assess any future decrease (or increase) in population levels (see the Information Needs section below).

Although harlequin ducks have disappeared as a breeding species from Colorado, as well as from several watersheds in Idaho and Montana, the factors responsible for local declines are not well understood. While habitat degradation on the breeding areas is often cited as a potential factor, the loss of adults on the wintering grounds (e.g., to hunting) may also have significant effects. Low reproductive rate, high breeding site fidelity, and delayed reproduction are all factors that will increase the difficulty of local populations to rebound from poor reproduction or low survival.

Management of Harlequin Ducks in Region 2

Implications and potential conservation elements

Several factors appear to be responsible for the variation in abundance and reproductive success of harlequin ducks in Region 2. Currently, harlequin ducks are restricted to breeding on relatively undisturbed, rapidly flowing rivers and streams with high elevation gradients. Observations have suggested that human disturbance during the nesting season may result in failed reproduction or even long-term abandonment of the breeding site. Because harlequin ducks occur at low population densities and are susceptible to disturbance during the nesting season, there has been little scope for studying the effects of forest management practices (e.g., logging, forest thinning, road building) on breeding status. In this respect, long-term monitoring of harlequin duck presence (both pairs and broods) on breeding streams may provide a rough indication of whether local habitat management is having negative effects. However, whenever the opportunity is available, research should be carried out to assess the effects of management activities on local harlequin duck populations.

Over 90 percent of all known harlequin duck breeding streams in Wyoming are on federal land, with approximately 40 percent in national parks and over 50 percent in national forests (Cassirer et al. 1996, Oakleaf et al. 2003). Within Region 2, the USFS is in control of over 95 percent of the known harlequin breeding habitat. Consequently, it is clear that habitat management for harlequin ducks will largely be carried out on National Forest System lands and that an active conservation plan for harlequin ducks should focus on activities within national forests. Such a plan might include a study of the relative health of currently utilized streams and rivers relative to unused areas. Such a study would help to clarify the role of stream pollution, acidification, and sedimentation in determining habitat suitability for harlequin ducks in Wyoming (and Colorado).

Surveys by Oakleaf et al. (2003) discovered harlequin ducks on streams that had not previously been surveyed. Such data raise the possibility that the Region 2 breeding population of harlequin ducks may be higher than is currently known. As a starting point in any conservation effort for harlequin ducks, a thorough

survey should be undertaken in the Shoshone and Bighorn national forests to gain a more accurate picture of the current distribution and abundance in Region 2. Such surveys would ideally be carried out on a regular (i.e., annual) basis in order to track any long-term population changes.

Harlequin duck reproductive success is relatively difficult to study. Females are secretive during the breeding season, nests are carefully hidden, and disturbance by researchers may cause lowered reproductive success. Consequently, assessing the role of forest management practices on harlequin duck presence and reproductive success is likely best accomplished during mid-summer, when broods can be counted. However, given that females often move broods downstream, it may be difficult to accurately survey breeding streams. As forest management practices may deter females from initiating reproduction on affected streams, it would be instructive to gather data on which streams were occupied each breeding season, relative to any nearby management activities. Over the long-term, gathering site-specific data on harlequin duck presence and reproductive success relative to nearby mining, logging, road-building, or other potential disturbances would help to build a robust data set on potential habitat management effects. It is important to point out that no studies have demonstrated any negative effects of forest management practices on harlequin duck reproductive success.

Re-establishment of the Southern Rocky Mountain population

The available evidence suggests that a small population of harlequin ducks inhabited the western slope of Colorado in the 1800s, but this was likely extirpated following extensive mining and timber extraction within many of the watersheds. If so, it is conceivable that such a population could become re-established either through natural dispersal or by reintroduction. Barrow's goldeneyes also formerly nested in western Colorado; but like harlequins were extirpated during the late 1800's (Parkes and Nelson 1976, Potter 1998). As with harlequins, habitat degradation due to extensive mining activity is the most probable cause. This species was recently found breeding on shallow lakes in the Flat Tops Wilderness of western Colorado, strengthening the probability that a small population of harlequin ducks might also become established, either by natural or artificial means. The success of any dispersing or re-introduced pairs would partly depend upon the quality of western slope streams and rivers in Colorado. The situation in southern Wyoming (e.g., the Wind River and Medicine Bow Ranges) is less clear as there is no historical information available on the breeding status of harlequin ducks in those areas.

There is considerable ongoing mining activity in southwestern Colorado, and pollution problems persist along several waterways there (State of Colorado 2002). In central Colorado, continued pollution from inactive mine sites remains a problem in several areas (State of Colorado 2002) including Summit County, one of the sites where harlequin ducks are presumed to have bred in the 1800s. Recent studies in Wyoming also suggest continued contamination from dormant and active mining sites in several of the state's watersheds (e.g., Ramirez and Armstrong 1992), with levels of various toxic chemicals well above recommended EPA levels.

If the reintroduction of harlequin ducks is considered, an initial step should be to judge the suitability of reintroduction sites. Such an examination would ideally include:

- sampling the proposed reintroduction sites for water quality (e.g., turbidity, pH), flow rates, and elevation gradients
- assessing the current level of human disturbance factors (e.g., recreational use, mining or timber extraction activities) within the watershed
- sampling invertebrate abundance for an index of suitability relative to harlequin duck food habits

Baseline data on those factors should also be collected along known breeding streams in northwestern Wyoming, thus providing a known database on the quality of streams used by harlequin ducks.

Tools and practices

Habitat management

Published recommendations for forest management practices that may aid harlequin ducks are presented in **Table 6**. Most of these recommendations have come from the 1996 USFS/BLM harlequin duck conservation plan (see Cassirer et al. 1996 for comprehensive details); in general, they fall under two categories: 1) maintain the quality of greeding habitat, and 2) minimize disturbance along breeding streams.

Table 6. A summary of habitat management recommendations for harlequin ducks in Region 2. For expanded details on these recommendations, see Cassirer et al. (1996).

Recommendation	Presumed benefits
Introduce buffer zones along montane riparian habitats	Protect nesting cover, maintain water quality, and decrease disturbance to breeding ducks
Avoid activities (e.g., clear-cut logging) that may alter the natural water flow regimes of montane streams or rivers	Preserve the natural flow regime and avoid high early season flows (which decrease reproductive success)
Avoid building new roads near riparian areas and eliminate/ stabilize obsolete logging roads	Minimize human disturbance, decrease sedimentation, and maintain natural water flow
Prevent livestock grazing along stream/river banks	Maintain streamside vegetation, water quality, and water flow
Manage water development proposals along breeding streams	Maintain stream connectivity and water flow, avoid excavation (e.g. gravel) during the breeding season
Require approved minerals management plans in watersheds that support harlequin ducks	Maintain long-term water quality and minimize human disturbance during the breeding season
Discourage or prohibit recreational boating, trail and campground construction, and (May-June) fishing activities on harlequin duck breeding streams	Minimize disturbance to breeding harlequin ducks
Develop education materials (e.g., brochures) for the public	Educate the public as well as land managers concerning harlequin duck biology and potential disturbance issues

More specific recommendations include:

- ❖ minimize logging and mining along high elevation streams
- ❖ avoid activities that may lead to altered water flow patterns
- ❖ maintain high water quality
- ❖ minimize human disturbance along breeding streams
- ❖ develop educational material to inform the public about disturbance

Minimizing mineral extraction and logging activity along fast-flowing creeks and rivers is likely to have the greatest positive effect on harlequin ducks as it will lead to decreased disturbance to breeding ducks, as well as maintain water quality and hydrological patterns. It also has the benefit of reducing disturbance as a lack of roads and access reduces human visitation. The extirpation of harlequin ducks from Colorado may have been largely due to the degradation of streams and rivers from mining runoff and heavy logging activity. When extracting timber, wooded buffer zones along waterways help to minimize runoff and sedimentation. Pollution from mining activity continues to be a problem in Colorado, with contamination of nearby waterways continuing long after mining operations have ceased (State of Colorado 2002).

As mentioned earlier, any forest management activities carried out in close proximity to harlequin duck breeding streams should include a follow-up study to assess whether any effects (whether negative or positive) are seen (e.g., a lack of harlequin ducks, or an increase in the number of occupied breeding streams).

Tracking individuals

Several studies have analyzed the costs and benefits of various forms of marking and tracking individual harlequin ducks. Esler et al. (2000) found no negative effects of implanted radio transmitters on the survival of harlequin ducks in Alaska. Regehr and Rodway (2003) studied both the longevity and effects of nasal discs and colored leg bands on wintering harlequin ducks in British Columbia. Nasal discs were prone to loss while colored leg bands became discolored, rendering both methods problematical except for short-term studies.

In addition, males with nasal discs showed only 28 percent pairing success, relative to 89 percent success for males without nasal discs. Females with nasal discs showed lower rates of reuniting with their former mates than did those with no nasal discs.

Inventory and monitoring

An inventory and monitoring protocol has been developed for harlequin ducks, based largely on the species' biology within Region 2 and nearby areas. This protocol was originally developed by Cassirer et al. (1996) and is reproduced here in the **Appendix**. Note that the methodology outlined in the **Appendix** should be modified according to the goals of the study. For example, both brood and pair surveys may be undertaken to assess local stream occupancy, but brood surveys are the only method available for assessing local reproductive success.

The primary problem in assessing the conservation status of harlequin ducks will be in accurately censusing local populations. As noted elsewhere in this report, there are concerns that surveying techniques, although useful when standardized, are very sensitive to variables such as time of day, weather, and season. A full discussion of these points is found in Oakleaf et al. (2003). Surveys at different times of the year (e.g., May, June, July) each have their own drawbacks including poor weather, difficulty in spotting birds after the relatively visible males have left the breeding streams, and the secretive behavior of females and broods. Observer experience should also be standardized as much as possible. Aerial surveys can cover large areas, but these are susceptible to weather conditions and are relatively expensive.

Schirato and Perfito (1998) suggested that ground surveys along breeding streams should ideally be carried out six times over the course of the breeding season. Repetition is necessary due to inaccuracies resulting from overlooking birds (because they are relatively secretive during the breeding season) and from misclassifying migrant and post-breeding birds as local breeders. Cassirer et al. (1996) suggested that surveys of breeding streams be carried out along the length of the streams, from the headwaters to any confluence downstream. Obviously, such surveying may be time-consuming and/or logistically difficult.

The only method available for assessing reproductive success is to perform brood surveys in early August (Cassirer et al. 1996). Although surveys can be initiated earlier in the season, accurate assessment of reproductive success is better accomplished with later surveys, when ducklings are closer to fledging age. Cassirer et al. (1996) provide details on methodology for brood surveys.

Information Needs

The main information needs for harlequin ducks in Region 2 are summarized in **Table 7** and are discussed more fully below.

Breeding distribution

Harlequin ducks occur in low densities along scattered breeding streams/rivers in Region 2. However, there is a need for a more coordinated effort to survey streams within and just outside the current known

Table 7. A summary of proposed information needs for a better understanding of the conservation of harlequin ducks in Region 2.

Information needed	Technique/Methodology	Benefits
Expanded knowledge of current breeding streams in Wyoming, including the Bighorn and Wind River ranges (Bighorn and Shoshone national forests)	Pair and brood surveys as outlined in **Appendix**.	Clarifying the current breeding range in Wyoming
Demographic data (e.g., survival, dispersal, age-related reproductive success)	Local-scale studies of reproductive success and banding of adults and ducklings	Modelling population viability, as well as clarifying the effects of habitat treatments
Longitudinal studies of the effects of forest management (e.g., logging, road building, fire)	Between-year studies of harlequin duck abundance and reproductive success; before/after studies	Clearer understanding of how treatments affect harlequin duck population biology
Preferred habitat components in Region 2	Quantify habitat variables (e.g., Machmer 2000) along used and unused streams	Better understanding of which factors are most important in determining site adequacy
Determine whether human recreational activities are impacting Region 2 harlequin ducks	Correlate duck presence in early summer and/or reproductive success with measures of human disturbance	Clarification of how current recreation (e.g., flyfishing) levels may be impacting nest site choice and breeding success

breeding range in Wyoming. This effort should include personnel from the National Park Service, the USFS, and the BLM. Survey techniques, as outlined by Cassirer et al. (1996), are presented in the **Appendix**. Although Grand Teton and Yellowstone national parks are outside Region 2, they adjoin the western edge of Region 2 and therefore likely support duck populations that act as source populations for Region 2.

Preferred habitat feature

Although we have a general picture of the preferred breeding habitat of harlequin ducks, a quantification of habitat variables (e.g., see page 6 in Machmer 2001 for a sample data collection sheet) on known breeding streams, as well as nearby unused streams, would help to clarify the importance of variables such as streamside forest cover, stream attributes (e.g., depth, channelization, flow), and human disturbance levels. Such information would help to guide future management decisions regarding the suitability of different watersheds as potential harlequin duck breeding streams.

Demography

Bengtson and Ulfstrand (1971) suggested a link between local food resources and the percentage of females that skipped breeding in Iceland. This link has been cited often but has not been corroborated in other areas. The factors that affect the breeding probabilities (e.g., local food supply, female age) of females should therefore be studied more closely.

Forest management effects

In areas where forest management practices occur near known harlequin duck breeding streams, assessing the effects of such activities on the presence of adults and on reproductive success would provide valuable information for future management efforts. Such studies would ideally be carried out before and after management activities. For example, when logging or forest thinning activities are planned for a coming year, status surveys of any potentially impacted streams/rivers would ideally be carried out before, during, and after the manipulations. While such studies would not result in a statistically robust data set, if repeated over time and in different areas, they should result in a better understanding of how land management activities may affect harlequin duck distribution and breeding success.

Mining

Mining along high-elevation streams and rivers remains relatively common in western Colorado and Wyoming, with continued problems due to leaching of chemicals into nearby water sources (State of Colorado 2002). Side effects (e.g., logging, water pollution) of mining are thought to have caused the extirpation of harlequin ducks from Colorado in the late 1800s and it is clear that, at least in some areas, mining activities continue to pose a barrier to the recolonization of potential breeding streams by harlequin ducks. A comparison of water quality among known (Vallecito Creek, La Plata County) and presumed (Blue River, Summit County; Colorado River tributaries in Grand County) historical breeding streams in Colorado with current breeding streams in Wyoming (Thorofare Creek, Yellowstone River, Moose Creek, North Fork Buffalo Creek; Oakleaf et al. 2003) would provide a good measure of whether water quality may be hampering the re-establishment of harlequin ducks in Colorado and in some areas of Wyoming.

Relationships between forest stand history (e.g., logging frequency, stand age) and harlequin duck reproduction could be studied in Region 2. Almost half of all of the known harlequin ducks in Wyoming breed in national parks, where forest management activities are minimal (Oakleaf 2003). Such areas could thereby provide a baseline data set for comparison to more disturbed areas. Comparing the stand histories of watersheds that support breeding harlequin ducks with those that do not may suggest which factors are important in determining the use of potential breeding streams.

Human recreation effects

As noted by Cassirer et al. (1996), responses of harlequin ducks to human disturbances may vary among individuals and among breeding areas. Consequently, a study to measure human recreation levels along streams, in addition to the use of those streams by harlequin ducks would be very informative. As National Forest System lands are managed for multiple uses, human recreational activities can be intensive during the summer months. Determining whether short or long-term abandonment of historical breeding streams may be, in part, due to such activities would be a key piece of information in conserving local populations of harlequin ducks.

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APPENDIX

Inventory and Monitoring Protocol for Harlequin Ducks

(Modified from Cassirer et al. 1996)

These inventory and monitoring guidelines are based on data collected in Idaho, Montana, and Wyoming breeding areas. Breeding chronology of harlequin ducks varies by area, for instance harlequin duck arrival and breeding activities in Grand Teton National Park, Wyoming occur two to four weeks later than in northern Idaho (Wallen 1987, Cassirer and Groves 1994). Therefore, this protocol is only specifically applicable to the area it was developed, and other areas where similar breeding chronology has been documented.

Monitoring

A rotational survey design (Skalski 1990, 1995) has been selected for monitoring harlequin duck pair numbers and productivity in the U.S. Rocky Mountains. All harlequin duck breeding streams and probable breeding streams that can reasonably be surveyed are incorporated in this survey design. Streams currently of unknown status should be added to this list in the future if inventory efforts reveal that they are harlequin duck breeding streams. Selected "bellwether" streams are monitored on an annual basis. These streams should be selected based on relative accessibility, consistence of harlequin duck use, and distribution throughout the Rocky Mountain breeding range. A minimum of 25 percent of the remaining breeding or probable breeding streams in the subprovince are randomly selected and surveyed on a rotational basis. Monitoring should be conducted whether or not any management activities are scheduled in the area.

A population estimate is derived by combining the actual number of pairs observed during pair surveys on the "bellwether" streams" and "rotational" streams. The number of pairs observed on the "bellwether" streams is summed and the average number observed on the rotational streams is applied to all remaining breeding or probable breeding streams (Skalski 1995).

$$\hat{N}_T = r\bar{N}_r + (M - r)\bar{N}_p$$

Where M = the total number of breeding streams.

N = the number of pairs observed.

r = the number of bellwether streams surveyed every year.

p = the number of nonbellwether (rotational) streams surveyed every year.

It should be noted, however, that this population estimate is an index, and it likely underestimates the true population size because of the observability of harlequin ducks (see pair surveys under survey methodology).

Variance is estimated assuming a total count on the bellwether streams, and a variance estimate for observations on the rotational streams.

$$Var\,\hat{(N_T)} = (M - r)^2(1/p - 1/M - r)S^2$$

where

$$s^2 = \frac{\sum_{j=1}^{p} (Np_j - \hat{\bar{Np}})^2}{(p-1)}$$

Inventory

Inventory should be conducted on streams where harlequin ducks have been observed but where breeding status is unknown and on streams that are potentially suitable harlequin duck habitat. On streams where breeding status is unknown, a minimum of four surveys, three of which are pair surveys, should be conducted over a period of three or more years prior to determining stream status. On streams that are potential habitat, but where no ducks have been observed, at least four surveys should be conducted over two years, including at least two pair surveys, prior to determining stream status. However, if a brood or nest is observed at any time during surveys, the stream will be classified as a breeding stream.

Survey methodology

Timing is critical for both inventory and monitoring surveys. Timing is probably the most important factor in survey success. For this reason, most surveys must be conducted specifically for harlequin ducks, rather than in combination with fish or other wildlife surveys. Surveys are conducted during two periods: spring pair surveys and summer brood surveys.

Pair surveys

In the northern Columbia Basin and Rocky Mountain Front subprovinces, spring pair surveys should be conducted between 25 April and 25 May. In the Intermountain subprovince spring pair surveys should be conducted between 5 May and 15 June. Although these are the periods when pairs are most likely to be observed, even when conducted during this period, surveys underestimate the actual number of pairs present by an average of 31 percent (Cassirer and Groves 1994). Because count accuracy can be variable, at 2 surveys should be conducted during this period for monitoring purposes. The survey with the highest number of ducks should be used for monitoring estimates.

Brood surveys

Brood surveys conducted for monitoring purposes should occur between 15 July and 5 August in the northern Columbia Basin subprovince and between 1 August and 21 August in the Intermountain subprovince. Although ducklings hatch several weeks prior to these dates in both subprovinces, because of mortality rates typically occurring in young ducklings, surveys conducted during this period give a more accurate estimate of ducklings fledged. Ducklings should be aged by plumage development (see Cassirer et al. 1996) during brood surveys. Inventory surveys for presence only can be conducted as early as 1 July in the northern Columbia Basin and as early as 15 July in the Intermountain subprovince.

Inventory surveys should cover the entire stream from 2nd- or 3rd-order headwaters to the mouth. Inventory of this area should be conducted during the spring, and again during the summer, (or until ducks are observed, whichever is first) for at least two years before determining stream status. Therefore, inventory should be an ongoing program, not simply associated with proposed management activities.

Little specialized equipment is required for harlequin duck surveys. Some equipment that may be useful is:

- 8 to 10 power waterproof binoculars
- Felt-soled wading boots
- Neoprene stocking foot chest waders

Surveys can be conducted during any weather and at any time of day. Surveyors should use binoculars as much as practical, particularly in long, straight stream reaches. Harlequin ducks are commonly observed sitting on instream rocks or on the streambank, swimming or feeding in the middle of the stream, or paddling along the bank eddy. In the spring, the male is usually spotted first. Look carefully for the female nearby; the white spot on the side of her head is usually her most conspicuous feature. Both the male and female appear dark in flight, with no white markings on the underside of the wings.

Surveys can be conducted on foot, by boat, or by driving next to the stream. Walking is the best way to survey most streams. Walking surveys can be conducted in an up- or downstream direction. It is easier to survey downstream. However, the ducks do not swim as quickly upstream as they float downstream, and they are more observable when surveys are conducted going upstream. Also keep in mind the direction of the sun; observability can be greatly reduced on surveys conducted in the direction of the sun. If a road is available, use a crew of at least two people. Drop one person off at the beginning of the survey reach, a second person drives to a midpoint, preferably where the truck is visible from the stream or at a bridge or trail crossing, and walks to the end of the survey reach. After ducks are observed move off the stream to walk around them. When surveys are conducted in a downstream direction, you can often get closer to the ducks by making a wide circle around to get below them and approach from downstream. Count on covering about 1 mile per hour in spring surveys and 1.5 miles per hour in summer surveys. Because the ducks are mobile, enough people should be surveying to cover the entire stream in one day.

Boating is a very good way to survey, especially in the spring. Rafts or drift boats are best because one person can row while one or two passengers look for ducks. Fifteen to 20 miles of stream is a reasonable distance to cover by boat in a day, but the distance covered will vary with water conditions and access. Kayaking is also a good survey method and may be the only way to cover some streams at certain times of year. Depending on the stream and season, kayakers should be comfortable running class IV or V water and should also be familiar with harlequin ducks. Inner tubes may be used in summer surveys when the water is too low for boating but too deep or swift for walking. A wet suit or neoprene chest waders are usually necessary when inner tubing, even in warm weather.

Driving surveys can be conducted by two people along roads that closely follow the stream. Drive slowly with the observer in the passenger side of the vehicle

next to the stream or in the back of a pickup. Check areas where the stream is not in full view of the road on foot.

The spring pair survey period coincides with peak spring runoff in the Rocky Mountains. Therefore walking surveys of all but the smallest streams will usually be conducted by hiking along the streambank. Surveyors should be prepared for inclement weather and snow. If roads are not plowed, snowmachines may be necessary to get to survey areas. Camping out may be required to cover the upper reaches of some streams.

Streams will be relatively low during brood surveys, and walking surveys can be conducted by a combination of wading in the stream and walking along the bank. Felt-soled boots with neoprene socks and wool socks are recommended for walking in the stream. Stocking foot chest waders with felt-soled boots may be useful in cooler weather or higher water.

Data Collection

Record data on a standardized form (suggested form below), and enter the information into a computer data base. Please send copies of all inventory and monitoring data, even when no ducks are observed, as well as observation reports to the appropriate Conservation Data Center or Natural Heritage Program.

Harlequin Duck Survey Form

Surveyors' names: _____

Address: _____

Date: _____ Time start: _____ Time end: _____

Stream name: _____

Start location: _____

Start UTM coordinates: _____

End location: _____

End UTM coordinates: _____

Distance covered (km): _____

Type of survey (walk, boat, drive): _____

Observations/Comments: _____

Harlequin Duck Observations

Note: Idaho, Montana, Wyoming and several coastal states and provinces have marked harlequin ducks. Colored nasal markers on the bill, and colored, numbered, and metal legbands on both legs are being used. Please check for marks on all harlequins and include a detailed description of any observed.

Time: _____ Number: _____ Sex: _____ Age class: _____

Location: UTMN _____ UTME _____

T _____ R _____ S _____ 1/4 _____

Activity/Comments: _____

_____

Time: _____ Number: _____ Sex: _____ Age class: _____

Location: UTMN _____ UTME _____

T _____ R _____ S _____ 1/4 _____

Activity/Comments: _____

_____

Time: _____ Number: _____ Sex: _____ Age class: _____

Location: UTMN _____ UTME _____

T _____ R _____ S _____ 1/4 _____

Activity/Comments: _____

_____

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